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WATER BIRDS AND WETLANDS OF BANGALORE

A report on the status, water quality, plankton and bird populations of the lakes in and around Bangalore and Maddur, Karnataka, India

M. B. KRISHNA
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Sponsored in part by the Department of Ecology and Environment, Government of Karnataka

Birdwatchers' Field Club of Bangalore
and
Bangalore Urban Division,
Karnataka State Forest Department

1996

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T. S. Srinivasa

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STATUS SURVEY OF LAKES IN AND AROUND BANGALORE AND MADDUR

T. S. Srinivasa

INTRODUCTION

Wetlands are areas of marsh or water, natural or artificial, permanent or temporary, either flowing or static, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six metres. This definition also includes man made systems and the lakes in the Bangalore area fall into this category.

WETLANDS AND THEIR IMPORTANCE

Wetlands are one of the most dynamic and productive ecosystems in the world. Fresh water wetlands occupy less than three percent of the area of the world. Waterfowl are the best visual indicators of the richness and diversity of these marginal areas between land and water. The diversity of waterbirds reflect the many ways of life possible for birds in wetlands. Waterfowl exploit a range of microhabitats. Each of these microhabitats can support a variety of different food sources.

The richness of a wetland for water birds depends on the diversity of microhabitats and the food sources available. The numbers of waterfowl a wetland can support depends on its size and most importantly, its biological productivity. This is the rate with which organisms in the wetlands multiply and are available for 'harvesting' by waterfowl. Most wetlands do not have all microhabitats and food resources possible and not all provide safe roosting sites. Thus different wetlands support different species of birds. Besides these ecological and biological aspects, wetlands play an important role in the hydrological cycle also.

LAKES OF BANGALORE

The lakes in the Bangalore area were built basically for hydrological reasons. This was for impounding the monsoon runoff in the valleys for use in lean seasons. They also helped in checking floods in recharging and maintaining the ground water table. Lakes also act as sediment traps and prevent clogging up of natural valleys and reduce erosion by regulating runoff. Over the years they acquired the status of wetlands, wherein their biological and ecological role also became significant.

These man made lakes have both deep and shallow water zones of varying extents and each of these areas are used by different groups of birds. The details are given in the section on birds. These lakes through their complex food webs continuously recycle raw materials and break down dead and decaying plant and animal matter.

The birdlife supported by such lakes further plays an important role in providing, through their droppings, raw materials in the form of major nutrients like nitrogen, potassium, phosphates and other inorganic salts, which though minor are essential. This helps to make the lake waters fertile and initiate food chains from the planktonic levels. This eventually makes the water body highly productive in overall terms. Since a major part of this water is used for irrigation in rural areas, the already fertile waters would be able to support a higher crop quality.

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LAKE SYSTEM

Every lake has three stages namely the catchment area, the lake itself, and the 'achkat' or the irrigated area down stream These stages combine together to form the 'lake system' and thus cannot be looked at in isolation The catchment area of the lake consists of a natural drainage basin or a watershed, with a number of small streams and nullahs, draining the runoff into a major valley system This valley system has a lot of natural check-dams and depressions which in turn act as silt and sediment traps, reducing the 'download' carried by the surface runoff

Each catchment area is an integrated system having small, medium and large lakes in succession Excess water of small lakes flow into medium lakes and finally into large lakes The over flow from large lakes drains into a stream or a river This extensive water storage system reduces the risk of floods and ensures fairly equitable water distribution

The lake has three main areas:

1) lake margin and foreshore
2) lake bed and
3) bund or embankment.

The foreshore area of the lake is the area from which the runoff enters the lake The foreshore area reduces the velocity of the inflow into the lake and minimises the erosion and the resultant silting of the lake Normally the foreshore area of a lake has mixed groves or tree monoculture, which prevents soil erosion

The lake bed is basin shaped with deepest part near the bund This helps to have maximum water storage and full capacity utilisation The bund is normally convex towards the foreshore area with inlets / outlets for irrigation, excess water drainage, etc

LAKE STATUS

To sustain the complex natural cycle coupled with hydrological and biological roles of a lake, it is important that a proper maintainence is ensured The lake catchment and the lake itself need protection and monitoring to prevent decline and abuse. Also, effective management of a lake system requires inputs from engineering, agriculture and biology It is with these perspectives that lake status data are being collected along with the Midwinter Waterbird Census every year To ascertain the suitability of irrigation and urban lakes as wetland bird habitats, a number of parameters that directly affect birdlife have been regularly recorded every year.

The lake status information is collected based on visual observation. To eliminate the errors which may arise due to observer bias, a standard data sheet is used (appended) Broadly the parameters recorded can be classified into:

1) lake structure,
2) water level,
3) water colour,
4) vegetation

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5) lake use and

6) threats and disturbances

LAKE STRUCTURE

The lake structure data consists of information relating to depth, lake margin, presence of mudflats, sedimentation, bed type, etc These physical parameters are important for the zonation of the lake, which in turn determines the species diversity For example, lakes with cut or walled margins support very few wading birds when compared to those with sloping margins As the city expands, more and more lakes are being walled up to restrict the water spread Of the 94 lakes surveyed, nearly 30 lakes had cut or walled margins

WATER LEVEL

Water level is a very important factor in determining waterbird populations and diversities Due to deficient rains in the past two years, nearly 23% of the lakes were dry while another 25% had little water This apart, the water holding capacity of most of the lakes are very low due to siltation and sedimentation The fragmentation of natural valley systems and isolation of lakes and catchment areas have contributed to the reduction of waterbirds at these lakes Of the 30 lakes which had high water levels, 25 are fed by sewage

WATER COLOUR

Lake water colour provides useful clues to make a quick preliminary assessment of some key environmental parameters influencing aquatic ecosystems Sewage eutrophication rendering water green has been observed in 23 lakes (23%) this year in contrast to 9 lakes (10%) in 1989 18 lakes (20%) in 1992 and 31 lakes (30%) in 1995 Only 13 lakes (14%) had clear water this year compared to 16 lakes (18%) in 1989 and 16 lakes (16%) in 1995

VEGETATION

Lake vegetation can be broadly classified into four categories:

1) floating

2) anchored floating

3) emergent and

4) submerged vegetation

The presence of vegetation in a lake makes the ecosystem more dynamic besides providing food, refuge and nesting sites for different species of waterbirds During the 1996 census, 49 lakes (52%) had emergent vegetation as against 33 lakes (33%) in 1995, 26 lakes (18%) in 1992 and 49 lakes (51%) in 1989. Floating vegetation was noted in 18 lakes (19%) this year while the figures were 11 lakes (11%) in 1995 and 20 (21%) lakes in 1989 Submerged vegetation was present in 17 lakes (18%) this year, while the figure was 14 (15%) for 1995 and 22 (23%) for 1989

LAKE USE

The lakes around Bangalore were constructed mainly for irrigation and secondarily for drinking water

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supply Their role as aquatic habitats for water birds was only incidental This being a fact the term 'use' attains a broader meaning. During the Censuses, the different uses the lake and the water were being put to, were recorded The appended table gives an abstract of the data collected. It was observed that only 30 percent of the lakes are used for irrigation The water distribution network is almost defunct with damaged or incomplete canal systems, damaged sluice gates etc. Fishing is being carried on in 25% of the lakes surveyed Cattle grazing in the grassy lake beds was observed in 35% of the lakes. Agriculture along drying margins is practiced in 21% of the lakes Lake waters were used for washing purposes in 36% of the lakes while it was used for drinking in 3% of the lakes Mud-lifting was recorded in 30% of the lakes and brick-making in 38% of the lakes.

Uses	1996	1995	1992	1989
Numbers				
Fishing	24	18	32	-
Brick-making	36	35	42	50
Grazing	33	10	15	-
Mud-lifting	31	38	48	56
Agriculture	20	14	28	38
Irrigation	27	39	-	-
Percentages				
Fishing	25%	18%	23%	-
Brick-making	38%	35%	30%	52%
Grazing	35%	10%	10%	-
Mud-lifting	33%	38%	35%	59%
Agriculture	21%	14%	20%	38%
Irrigation	28%	39%	-	-

THREATS AND DISTURBANCES

Wetlands are fragile ecosystems and are susceptible to damage even with only a little change in the composition of biotic and abiotic factors The quality and quantity of water holds the key to the health of the ecosystem and any change in physical and chemical composition of water brings about a drastic change Wetlands as waterbird habitats are threatened because of inadequate water holding capacity, excessive withdrawal, pollution due to raw sewage and sullage, industrial effluents, eutrophication, leached fertilisers and insecticides Once they become unsuitable to wildlife it is but natural that they become unsuitable to man also in course of time

The main problems confronting lakes in and around Bangalore are discussed below It should be remembered here that many of these notes from [1] are still largely relavant and no improvements in the lake habitats have been seen from that time

LOSS AND FRAGMENTATION OF CATCHMENT AREAS

The unplanned rapid growth of Bangalore and its suburban areas have resulted in the loss of the catchment area for nearly 35% of the lakes surveyed. This means that the water flow to the lakes is

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very less as the natural drainage basin is disrupted. Added to this is the unscientific exploitation of ground water resulting in dropping of the water table. For nearly 40% of the lakes, sewage is the main source of water. Compounding this problem is the loss of vegetation and ground cover in the catchment area resulting in large scale siltation and corresponding reduction in water storage, even during good rainfall years.

SEWAGE AND EFFLUENTS

As new layouts spring up everywhere and the BWSSB is unable to treat even 40% of the waste water produced, the easiest way of disposal of sewage and other effluents is to let them into the natural drainage system and then on to the wetlands.

During the Census, the presence of sewage and varied degrees of eutrophication have been recorded from 28% of the lakes (10% in 1989, 13% in 1992 and 16% in 1995). 25% of the lakes had green waters this year as compared to 8% in 1989 and 28% in 1995. Other effluents are probably reaching 8% of the lakes (3% in 1989). It is estimated that nearly half of Bangalore's demand for fodder and 30% of the vegetables are grown with these untreated waters.

THE EFFECTS

Sewage alters the status of the wetland. It brings in enormous quantities of nutrients in to the system and enables unregulated growth of algae. This raises the BOD levels leading to anaerobic conditions which result in bad odours. This could be detrimental to the growth of other flora and fauna.

Depending on the physical and chemical composition, other effluents cause harmful effects. Fish deaths under such conditions have been recorded earlier. Also, sewage with higher concentrations of suspended solids result in turbid waters and increased sedimentation. Industrial wastes without treatment could be reaching 8.5 percent of the lakes.

Sewage increases the growth of water weeds (like Hyacinth, for example). This reduces the penetration of sunlight into the water and could also reduce the water holding capacity of the lake. The lake becomes a rotting bed with stagnant water leading to stinking surroundings and a fertile breeding ground for mosquitoes.

RECOMMENDATIONS

Efforts should be made to treat the sewage waters at least partially before it is released into the lake or wetland. BOD and suspended solids must be lowered to acceptable limits before sewage flows into the lake. The example of Tindlu lake could be a model for other sites. Cost effective biological treatment methods can be employed along with primary treatment so that the quality of the ecosystem is not affected due to sewage.

MUD-LIFTING AND BRICK-MAKING

The lake bed silt and mud is traditionally used as manure and for small scale construction locally. The rapid growth of Bangalore and consequent demand for building materials has resulted in mud-lifting and brick-making on a large commercial scale. With little or no control by the Mines, Revenue or

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Forest departments, this activity is rampant and indiscriminate causing enormous damage to the lake structure and its ecosystem. Mud-lifting was observed in 33% of the lakes this year as compared to 59% in 1989

Brick making was recorded in 36% of the lakes this year compared to 46% in 1989. Brick-making destroys the shoreline and foreshore area of the lake and causes disturbance to waterbirds Brick-making should be prohibited within one km of the lake's high-water line

THE EFFECTS

Indiscriminate Mud-lifting from the lake bed severely affects the ecosystem The vertical walls of the pits lead to enormous silt movement once water starts flowing in during the rains This leads to high turbidity, reducing the depth to which light penetrates into the water thus decreasing the productivity of the lake Mud-lifting destroys the lake structure, damaging the shoreline and lake margin This results in bird habitat loss

RECOMMENDATIONS

1) There should be open and closed seasons for Mud-lifting Mud-lifting should be allowed only in dry months

2) Portions of the lake suitable for Mud-lifting should be identified and Mud-lifting allowed on a six year rotation basis

3) Pits should have sloping walls and not steeply cut walls. This reduces silt movement and turbidity levels.

4) There is a need to permit silt to be lifted in many lakes so that desilting takes place

5) Collection of a levy for Mud-lifting is necessary and the Mud-lifting activity should be monitored and regulated

6) Monitoring and detailed studies of lakes are required.

POACHING OF BIRDS

Waterbirds, especially the larger ones like ducks, geese, storks, ibises, and cormorants, are hunted on a large scale. This illegal activity reaches its peak between October and April when migratory waterbirds are present in large numbers Claptraps, noose traps and guns used extensively in medium and large lakes. In Madhure kere four clap traps were seized by the Forest Department during the census These traps are made of bamboo frames supporting a fishing net and are operated using long GI wires. Poaching was recorded in 8 lakes (7 5%) this year while the corresponding figure in 1989 was around 35%. Though there is an apparent reduction, this is due to the fact that the number of dry lakes in 1996 was much more than in 1989.

THE EFFECTS

Hunting of any kind disturbs the feeding, roosting and breeding of birds Birds are very sensitive to disturbance due to sound and intrusion Prolonged hunting drives away birds from wetlands leading to

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complete abandonment

RECOMMENDATIONS

Hunting pressure on the wetlands needs to be eliminated completely. The relevant clauses of the Wildlife Protection Act of 1972 and its amendments should be publicised The media can be used to highlight the importance of waterbirds and the resulting benefits in protecting them Monitoring the birdlife should also be taken up on a more intensive and larger scale Vigilance should be stepped up during the period from October to April Important sites should be declared as protected areas and developed into bird sanctuaries

SILTING AND SEDIMENTATION

With loss of vegetation in the foreshore and catchment, sedimentation and silting of the lakes have reached alarming proportions In earlier years, lakes were desilted regularly by the villagers during the dry seasons But with lakes passing on to the Government, desilting is almost non-existent in most of the lakes

THE EFFECTS

Silting reduces the water storage capacity of the lake Thus, even in good rainfall years, the water storage in the lake is very low. This leads to a reduction in the number of crops taken and in the irrigated area With water being very shallow, deep water birds such as ducks will not be able to safely roost in the lakes

RECOMMENDATIONS

Desilting should be taken up on a priority basis in medium and large lakes. The dredged silt could be used as manure and for brick-making and for other construction activities. The foreshore should be vegetated to reduce erosion and silting Only 33% of the lakes had foreshore vegetation while in the rest it was non-existent or degraded. Silt traps in the form of check dams and trenches should be used to reduce the quantity of silt coming into the lake

ENCROACHMENT OF LAKE BEDS

Lake beds are reclaimed for various purposes sounding a death knell for the lake Apart from Mud-lifting and brick-making which have been discussed earlier, encroachments are mainly for the following reasons:

1) residential purposes
2) agriculture
3) slums and housing
4) road building and other developmental activities

Bangalore has a long history of conversion of lake beds into residential extensions The rapid growth of the City has given a fillip to this activity Nearly 30% of the lakes had either residential areas in their fringe or have been partially converted into layouts.

Cultivation of crops is extended from the neighbouring agricultural lands till the water line In some

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cases, land filling and walling of the lake margin have been observed. With the government turning a blind eye to this encroachment, it has reached an alarming proportion. Almost 22% of the lakes have this threat.

Apart from these two main causes, the springing up of slums in the lake area has also increased with 13% of the lakes being surrounded by slums and unorganised housing

THE EFFECTS

Encroachments not only affect the lake directly but also bring other disturbances closer to the lake Increased human activity disturbs birds to a great extent. Besides the lake margin and the foreshore vegetation get affected. Sewage from nearby residential layouts are let into the lake directly. The shorebirds and reed birds that are dependant on the shoreline and its vegetation respectively, loose their foraging and breeding habitats. Land-filling results in severe sliting of the lake bed The effective area and hence the water storage capacity are reduced, leading to a slow but certain death of the lake The slum dwellers also use lake beds as open air toilets resulting in unbearable stench. Habitations also bring garbage closer to the lake

RECOMMENDATIONS

Encroachments need to be removed and adequate immediate protection to the lakes ensured. Protection should include not only the lake proper but also an area outwards from the high water mark to around 500m where developments are monitored and appropriate measures taken so that the long term quality of the lake habitat is ensured

POLLUTION

Other major threats are dumping of industrial wastes in about 9% of the lakes Garbage dumping is in 10% of the lakes and Land-filling in 2% of the lakes. Of these, industrial wastes pose a major health hazard and untreated effluents or solid wastes destroy the lake ecosystem With the absence of scientific methods of disposal and solid waste management, garbage dumping is becoming a major threat to the existence of lakes. Haphazard dumping of garbage around the lake results in chocking of the wetland.

DATA ANALYSIS AND INTERPRETATION

The lake status data collected during the surveys of 1995 and 1996 were compiled and co-efficients of similarity values were obtained using the methodology already described in the section on birds The results of a cluster analysis were used to plot a dendrogram depicting the results

CLUSTER ANALYSIS

The appended *Graph* shows a dendrogram for the parameters on which data were collected. The linkages at different levels between the parameters reflect the degree of association and many of them show established patterns. One such pattern is the relation between sewage and green water which in turn is linked to sedimentation, floating vegetation and algal blooms. Similarly brick making and Mud-lifting are linked with muddy waters. Submerged vegetation is seen to be associated with

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clear water The threat parameters also appear to be close linked These patterns could be the starting point for further studies

SCOPE FOR FURTHER WORK

It is suggested that long term monitoring and status studies need to be taken up. The subtle patterns indicated need further investigation as well as comparison with the published literature to detect inter-relationships between different parameters. Advanced statistical techniques can be used for a refined analysis to help data interpretation.

Since most of the parameters are visual characters, association with physical, biological and chemical aspects have to be investigated to get an overall picture of wetland status. Lakes should not be viewed in isolation and hence the lake systems across natural valley systems need to be studied to assess impacts.

CONCLUSION

The suitability of the lake habitat decides the variety and density of wetland birds It is clear from the section on birds that the frequencies of occurrence of bird species over the years (1987 to 1996) is almost constant where as the distributions are not Therefore, a large number of wetlands need to be protected simultaneously not only for the birds, but for other biota as well.

OVERVIEW

Over the years the lakes have fallen into neglect. Siltation and consequent reduction in the storage capacity loss of catchment areas, encroachment, reclamation and unchecked flow of effluents, have all contributed to the present deterioration Lakes in urban areas stand as a mute testimony to the hollow claims of 'Civic Sense' by the educated and elite citizens, and apathy, ineptness and inefficiency of the civic bodies The lakes inside the corporation limits of Bangalore, instead of adding to the aesthetics of the surroundings, have become 'Eye Sores'. Instead of enjoying a quiet evening walk by the lake, one has to close one's nose and take to heels to escape from the swarms of mosquitoes Ulsoor Lalbagh Yediur, just to mention a few have turned into cess pools

While specific recommendations have been made for each of the major threats, a few general suggestions are outlined here to save the lakes in and around Bangalore:

1) It is advocated that major wetlands such as Hosakote, Byramangala, Bellandur, etc are declared as nature reserves and protected

2) The boundary of the lake should be clearly demarcated to prevent encroachment

3) Periodic selective de-weeding and desilting is necessary

4) The foreshore should be vegetated

5) Protection to birds has to be ensured during the breeding and migratory seasons

6) Creating public awareness through the media as well as audio- visual presentations should be made

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7) There should be regular monitoring of important sites

8) Research on ecological and conservation related issues should be encouraged

9) Boating should be stopped in important wetlands as it leads to lot of disturbance to birds

10) As most of the lakes are 'engineered' and not natural, the role of Engineers and Hydrologists in conservation and restoration efforts are very important

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THE PLANKTON COMMUNITIES OF BANGALORE AND MADDUR

B. K Chakrapani

INTRODUCTION

This chapter reviews results of the plankton surveys conducted during 1989 and 1995 in the lakes in and around Bangalore and Maddur The studies have covered an overall total of 88 sites (lakes) with 44 lakes being common for both years and with 28 and 16 lakes being exclusive to 1989 and 1995 respectively A few water bodies considered to be of highly valuable ecological importance for the future have also been additionally covered during 1995

"Plankton' is an ecological term, referring to aquatic organisms which are pelagic i e , those which generally drift freely or are capable of swimming only weakly and most of the time are at the mercy of waves and currents active in the water bodies they inhabit This term is derived from Greek language in which it means 'wanderer' Plankton occupy the 'open water zone' between the surface and the bottom of a waterbody. These organisms being microscopic for one to appreciate their existence are therefore known very little to a lay person. They comprise of a myriad variety of organisms drawn from different phyla of plants and animals with fascinating structural or morphological features as well as survival tactics i e., the adaptive features of their own. The plants and animals among plankton are termed 'Phytoplankton' and 'Zooplankton' respectively

The plankton form an important and major compositional part of the foodchains and foodwebs in the aquatic ecosystem, apart from the larger organisms like mammals, birds, reptiles, amphibians, fish, molluscs, insects, other invertebrates, floating and emergent plants and organisms associated with them Such ecological associations can still be seen in some of the wetland habitats like tanks or lakes occurring in and around Bangalore The 'Phytoplankton' are the producers and are mainly composed of organisms wellknown by the common term 'Algae' Many of them would have existed earlier as organisms attached to substrates in the water bodies when they are termed 'Periphyton', and could later get free from their substrates to occupy a planktonic status Bacteria, fungi and viruses can also be planktonic but being much smaller, are classified as nannoplankton or bacterioplankton. The 'Zooplankton', to understand in simple terms, are mostly primary consumer organisms with very few secondary consumers. They would be mainly represented by animals like the protozoans; some sponges or their parts; invertebrates mainly represented by rotifers, crustaceans which commonly include cladocerans, copepods and ostracods; other miscellaneous members like insects, and their larvae and worms free floating eggs of some larger crustaceans and fish etc In the littoral wet soil zone too organisms smaller or as large as plankton exist In fact, it is very difficult to be able to represent the wide variety of the groups/ communities of the plant and animal organisms which one could come across as plankton, in its entirety However it is certainly possible to do so to a large extent for some specific or assigned habitats, the area of coverage and habitat diversity being fairly limited

In short it can be considered that plankton organisms can belong to different taxa of plants and animals. However it would be a matter of great curiosity and interest for a lay person with an urge or

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inclination to learn about these organisms that the criteria for their inclusion (or the term classification for biologists to feel comfortable); as 'plankton', is based primarily on their size and for more detailed classification or grouping, on their mobility

In the case of pelagic plankton i.e. the plankton which are free floating and occupying the openwater zone; as being presently considered would only cover organisms larger than 52 u and smaller than about 5 mm These are the plankters, trapped within the 'Plankton net' (mesh size: 52 u), used during the sampling of plankton from the surveyed habitats. This inroduction has been largely adapted from [1&6]

ROLE OF PLANKTON

Knowing about plankton mainly from the ecological aspects and considerations, as related to freshwater lentic (i e., impounded or closed) ecosystems the major processes operational in them and hence their roles could be that of:

a) the efficient absorption of the incident solar energy and the available nutrients;

b) the conversion and consolidation of non-living matter through biological processes into living organic matter by producer plankton;

c) further conversion of producers by herbivores and secondary consumers into their body matter;

d) the decomposition of dead organisms and other organic matter into simpler basic organic, inorganic and gaseous matter; and

e) the recycling or resynthesis of matter obtained from the above processes into the next cycle of primary synthesis. Thermodynamic losses between each of the above steps are inevitable and are a part of the above natural processes.

The first true bio-synthetic or anabolic (building up) role in any aquatic lentic system like the wetland habitats, being presently considered, is triggered by the members of the primary producer (phytoplankton) community, followed by the primary consumer (zooplankton) community Catabolic (breaking down) role is mainly played by bacterial, fungal and other saprophages The above processes and the constitution of the planktonic community are highly dynamic and complex but nonetheless fascinating to comprehend. Thus plankton, both as producers and consumers play a pivotal role in transforming the solar energy inputs from one feeding level to the next higher in the food-chain This eventually leads to the supporting of larger organisms like insects, worms, other invertebrates including larvae, molluscs, fishes amphibians, reptiles etc., which in turn, could eventually support waterfowl also [largely adapted from 1&6].

The important link between the basal abiotic and the dead and decaying biotic (organic) matter and the living matter in waterbodies therefore, is provided by the primary (producer and consumer) organisms [6] It has been well documented and stressed by [13] that production levels in aquatic habitats are affected by morphological, physical and chemical factors operating therein. Thus, the quantum and more importantly, the diversity of the phyto and zooplankton are determined by the

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fertility and quality of the water to a large extent. Plankton in addition do provide considerable quantities of organic matter and nutrients into the nutrient pool of the ecosystem due to their short lifecycles.

It also becomes a point of importance and pertinence to consider along with the present context of knowing about wetlands that the fisheries resources with or without aquaculture practices undoubtedly form a most deserving component linked to wetland resource utilization. These are also supported by the plankton resources present in the wetland. It further becomes very important to develop and sustain a wholistic and balanced approach in terms of drawing out sustainable yields of existing endemic fish species from such habitats. Importantly such a process should not be delinked but should form part of the modern freshwater fisheries technologies adoptable in the present times.

It is thus advisable that the proper management of all prospective resources derivable from wetlands in future, should now be viewed from an 'urban multiple use' concept including conservation as a priority issue and others like environmental and recreational aspects for the habitats in and around Bangalore. Further, for their programmed future development considering the newly emerging contexts, a 'scientific eco-biological management' approach rather than an earlier emphasis on a 'techno-aquacultural management' approach should be adopted. In this sphere, the value of the diverse ecological roles that plankton play, would have to be given due importance and support.

A wide range of habitats exist, as made out out from field experiences during the survey of Bangalore's lakes both during 1989 and 1995 and these have been observed to be affected by various problems as well as some new developments including the existence of different forms of ecological pressures. These features also seem to be interestingly reflected by the plankton assemblages supported by these habitats showing up a wide variety of situations. The plankton populations reflect wide quantitative variations and diversities. Some of these aspects which affect the distribution and abundance of plankton are the bottom sediment criteria, sediment water interactions, water quality criteria, floral and faunal constituents and other ecological features. Such information is however largely not available for local situations and more so for the habitats affected by their closeness to large urban areas with dense habitations and sprawls like Bangalore, on a widely experienced scale and more practically important, at least on a generally prescriptive basis so as to help ecologically sound habitat management manoeuvres. Further, there appears to be a wide diversity in the urban influences which affect these habitats and hence, the respective plankton populations, as observed during the earlier surveys [as in 1].

Additionally, one of the most significant roles that plankton organisms can play by their abundance, distribution and diversity is that they serve as valuable Bio-indicator organisms whereby they can help assess at a fairly preliminary stage itself, the health status of any freshwater habitat. Attempts to use plankton as bio-indicators to plan habitat management efforts have not yet been adopted on an utilitarian scale in our country. Even the initial attempts if any, still remain essentially experimental but sadly, not satisfactorily prescriptive. It therefore becomes important that such efforts should at least be started now and the new learning is put to practical and preferably, field tests at a much faster pace as, the situations now seriously demand. If this is not done, all efforts would fall awfully short of the

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problems created and thereby posed anew Problems are further likely to get out of hand and worsen the prospects of the wide resource base accruable from such habitats in the immediate future.

THE NEED FOR LAKE PLANKTON SURVEYS

In the recent past, studies on 'plankton', 'limnology' (i.e , the science of freshwaters) and wetland ecosystems, all became inseparable from one another These studies have been gaining increasing importance since they help us in understanding the biotic-abiotic inter-relationships as well as the basic productive features of impounded water bodies [6] It is these relationships which sustain the aquatic ecosystems at the higher trophic levels In the present context, they critically influence the very existence of Bangalore's lakes as healthy and aesthetic wetlands which also support a diverse variety of vegetation and thereby also provide habitats to higher faunal members like birds and more specifically, waterfowl

In the above context, it was decided that it would be a highly valuable and ecologically meaningful effort to sample plankton and analyse them as a part of the status study of wetlands (with a historical beginning as the term irrigation tanks and is presently being referred to as lakes, as the latter term, would be more administratively useful than ecologically); which was first carried out in and around the city of Bangalore during January 1989, as part of the 'Annual Asian Mid-winter waterfowl census' A similar effort has been repeated after a time-gap of six years, in the similar fashion during the annual waterfowl census of January 1995. However, an additional objective this time was to look for changes which could have occurred over these years.

The present section on plankton has most of the salient features from the results of the survey and study carried out during 1989 as a report [1]; and the details of the status survey and study, which followed the sample collections during a similar effort in 1995 During both these times however, only a preliminary effort to qualitatively scan the plankton samples for their occurrences have been attempted

The objectives here were mainly to draw at least a representative list of planktonic organisms inhabiting the surveyed tanks and further, to look out for any remarkable changes in the form compositions i e . the assemblages of these plankton organisms in individual habitats and more importantly, in the context of the overall trends and ecological situations for the lakes of 'our dear Bangalore city'! At this point it is felt necessary to mention about the importance and worthiness of the effort to monitor the wide array of ecological aspects of the wetland resources of Bangalore along with plankton at regular intervals of 3-5 years and more frequently if and when the situations demand. This would, it is strongly felt help significantly to draw up management strategies to conserve and improve the wetlands around us from time to time. The effects of the improvement measures when implemented and fresh ideas relating to whether these efforts themselves need to be given a freshlook at times etc , can also be aided by such studies These views have been stressed in an overall sense in the context of wetlands (lakes) in and around Bangalore as early as in 1988 [in 11 & 12] A strong and desirable scope for a 'need based approach along with an intrinsic and ecologically dynamic operating management facility' would thus be created; whose returns would certainly be invaluable and welcome for the ecologically harried citizens of Bangalore

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METHODOLOGY

At each of the lakes sampled, plankton collections were made by straining 50 litres of tank water through a Hand-plankton Net (mesh size 52 m) Each sample was transferred into a labelled 50 ml polyethylene container and fixed with Leugol's iodine to prevent decomposition and to specially preserve the phytoplankton These fixed samples were then analysed in the laboratory using a Light-microscope From each of the samples, 2-3 sub-samples were scanned after spreading the fixed plankton organisms on a glass slide [methodology as in 1] and also by making use of the 'Sedgewick rafter cell' Three repeatitive scans were made to get as good a representative coverage for the plankton organisms as possible for individual habitats The plankters were identified using standard keys - mainly [2,3,4,5] and some others, on these aspects

The introductory information for describing most plankton groups has generally been adapted from [1] with the same serving as a baseline for future use

RESULTS AND DISCUSSION

A 'Qualitative plankton analysis' for the Sixty lake samples collected during the 1995 Waterbird habitats' survey was carried out and the salient features of the results are presented and discussed in this section Some characteristic features concerning the major planktonic groups and a few individual plankters where some clear and ecologically associated features can be linked etc , are also presented here However, such aspects have been kept brief and restricted to ecological contexts only Along with these results, some broadbased general comparisons based on the observations from the 1989 effort, have also been reflected wherever it has been found to be relevant. These comparisons have been handled in a more detailed manner in a seperate section

PHYTOPLANKTON

The organisms comprising phytoplankton are planktonic primary producers which convert the radiant solar energy into phytoplanktonic biomass, making use of oxygen, carbon-di-oxide and other nutrients present in the waterbody through the process of photosynthesis

The phytoplankton recorded during the survey of selected lakes in and around Bangalore as waterfowl supporting wetlands, have been presently considered under five major groups commonly used to group algae Phytoplankton for all purposes of understanding the ecology of freshwater bodies, comprise of algae and the individual types have been referred to as members or more specifically as forms.

MYXOPHYCEAE

Members of this group are also known as Cyanophyceae and are commonly termed as blue-green algae The presence or the abundance of especially some of their members, in the habitats is of great significance ecologically as, some of them serve as very good bio-indicators. They are not abundant in healthy habitats i e , where the nutrient supplies are not high or rich and are available only in balanced amounts However, when the most significant nutritive parameters like nitrogen and phosphorous are present in excess, eutrophic conditions result which can support some particular

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members in overwhelming abundance, resulting in well known conditions commonly termed 'Algal blooms' These conditions are predominantly caused by Myxophycean planktonic algae, which could be either non-filamentous or filamentous or both Generally, a predominance by only one or two members is commonly observed

During the present survey, thirteen forms excluding a maximum of two unidentified forms have been recorded During the 1989 survey, ten forms were recorded In the present analysis, the forms *Gloeocapsa, Rivularia and Tetrapedia* have been additionally recorded

Nitrogen is an important constituent in nature of all living organisms and is of special significance in relation to Myxophyceae Forms like *Anabaena, Aphanizomenon and Nostoc* sp., recorded from the surveyed habitats and others like *Gloeotrichia and Nodularia* sp , can directly fix atmospheric nitrogen like the leguminous plants can do on land Alternately, some of them can fix nitrogen from other nitrate sources in water *Microcystis and Oscillotaria* sp , are however known to become predominant when phosphates are in excess *Spirulina* sp , is a very well known nitrogen fixer and is universally known for its preferrence to an alkaline medium It is of significance to note an increase in its spread to more water bodies and of more concern, its predominance in some tanks, not observed earlier In general it is also important to know that for these nitrogen fixers to photosynthetize efficiently, iron (Fe) and molybdenum (Mo) in turn are very essential.

Observing the occurrence of Myxophycean members in the tanks surveyed, an eutrophic situation is seen in many of these habitats It is observed that there is a predominance of *Microcystis* sp., in 41 (i e , 68% of the tanks) followed by *Phormidium* sp . in 33 (i e , 55% of the tanks); the others being *Aphanizomenon* in 15, *Anabaena* in 13, *Oscillotaria* in 9, *Spirulina* in 7, *Coelosphaerium* and *Nostoc* spp , in 6 and *Lyngbya* sp in 5 lakes in that order of dominance. There were a few other forms occurring in fewer i.e , less than five habitats. It is also known that the *Microcystis* sp , is greatly influenced by the rate of supply of ammonia dissolved in the water which could be high in eutrophic conditions

The high distribution of *Microcystis* sp , (in 41 lakes) and *Phormidium* sp , (in 33 lakes) itself, is indicative of the widespread eutrophic situation of lakes proximal to Bangalore city Considering the trends of the spread of only the *Microcystis* sp , for example, it has shown an increase from 48 0 % during 1989 to 68 3 % during 1995.

CHLOROPHYCEAE

These algal members possess only the green chlorophyll pigment and are among the most diverse lake algal groups of Bangalore 34 members including two unidentified forms, excluding the Diatoms have been recorded during the 1995 survey whereas during 1989, 33 members had been observed Generally, very few of these members, can form blooms. However, it is known that a deficiency of iron can cause blooms of flagellated algal forms like *Volvox, Eudorina* and *Pandorina* spp. etc. However, as mentioned earlier, the presence of any blooms of blue-green algal forms. can bring about a very marked decrease in both the diversity and abundance of all other phytoplankton organisms especially the chlorophycean members Many of the Chlorophyceae members are filamentous and many of

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them are attached to various substrata in the lakes for support In such cases, some free ends get broken off or the members get free of the substrata and such free floating parts, also constitute the phytoplankton members

Eleven nonfilamentous members were recorded during 1995 By their distribution record among the 60 lakes surveyed, the more widely distributed forms have been *Coelastrum, Scenedesmus Pediastrum, Bulbochaete, and Volvox* spp , occurring in 17, 14, 13, 12 and 11 lakes respectively The remaining 6 members have occurred in less than 4 i e , % of the lakes These results are indicative of not a very good situation regarding the diversity of these algal members when the overall situation of Bangalore lakes are considered together It is known that high pollution loads are not supportive of these algal members.

Among filamentous chlorophyceae, twelve members have been recorded The most widely distributed forms were *Spirogyra Microspora, Zygnema and Mougeotia* spp , occurring in 37 27, 22, 21 lakes respectively To a lesser extent, *Closterium, Draparnaldia, Ulothrix and Chaetophora* spp , followed with occurrences in 18, 14 11 and 10 lakes respectively Four more forms occurred in less than 5 lakes. Thus, compared to the bluegreen algae, the distribution of chlorophycean members is much lower This is certainly indicative of the worsening situations observed among the lakes of Bangalore

DESMIDIACEAE (DESMIDS)

These are predominantly non-filamentous, small and very beautiful organisms except for very few filamentous forms They possess highly varied and fascinating but symmetric shapes and belong to the Chlorophycean group For a better appreciation of these desmids, they are being considered here as a subhead under the Chlorophyceae Eleven desmids including two unidentified forms were recorded during 1995 compared to ten members, during 1989 This group has some very important members who could be potential bio-indicators [adapted from 1] This potential is quite strongly observed by the occurrence of these members in very few lakes The maximum occurrence has been just by one form, viz , *Closterium* sp , that too in just 13 lakes This is further followed by *Gonatozygon* (in 9) and *Desmidium* spp. (in 5 lakes) All the rest are seen to occurr in just one or two lakes This picture of diversity and abundance itself is strongly and surely indicative of Bangalore's lakes being seriously and deleteriously ecologically affected.

BACILLARIOPHYCEAE (DIATOMS)

These members are popularly known as Diatoms These members also possess the green chlorophyll pigment and are small and extremely interesting algae They are usually made up of two valves and are perfectly radially symmetrical Their transparent and delicate valves are made of silica and because of this, the silica content of lake waters is of extreme importance in regulating their population dynamics These valves are also beautifully ornamented in many species and also form the basis for their taxonomical identities

They are also ecologically very important as, they form the food for many zooplankton members Their diversity was observed to be quite high During the 1989 survey of 72 lakes, twelve forms were recorded. In the present survey, the plankton analysis has shown up twentyfour forms including four

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unidentified members Among the most commonly occurring forms were the *Synedra* sp , (35; 58% of lakes), *Nitzchia* sp (31; 52%of lakes), *Frustulia* sp , (22; 37% of lakes) and *Navicula* sp , (18; 30% of lakes) The other forms were found to be less distributed Thus only six forms were found to occur in more than ten lakes All the unidentified forms together were found distributed in thirtysix lakes Going by the differences in the extent of distribution of the forms, it is likely that some of these forms could serve as useful bioindicators

DINOPHYCEAE

This group is represented by only one form i e , the *Ceratium* sp It is known to be a good food resource for zooplankton It possesses chlorophyll However at the same time as *Ceratium* performs the functions of a producer organism, it also possesses a large flagellum and is even known to feed on some small phytoplankton organisms It is therefore also classified by some workers under protozoans (zooplankton) It is therefore a very unique and interesting plankton form ecologically

It was recorded in very few lakes during 1989 and the situation appears to be similar during 1995 also; it being recorded from only five lakes From the analysis it appears to be restricted to larger water bodies, not much influenced by pollution from urban or industrial sources

GENERAL ASPECTS

In addition to the phytoplankton groups described above, many of the above forms are found in nature, attached to various substrates and live as periphytic organisms also Many of the diatoms have such an ecological status It is more important to appreciate that all such attached forms are ecologically very important in wetland habitats as, they provide rich food resources for browsing organisms many of whom are zooplankton forms

During the 1989 survey, a total of 56 phytoplankton forms were recorded from 72 lakes During the present survey of 1995, 66 forms including 8 unidentified forms have been observed For both the surveys, other items like fungal filaments, plant spore/ seed bodies were also seen In the present context however the records for such miscellaneous items are more of academic interest since, their detailed role as planktonic members is not so well studied or documented and therefore, possibly less understood

ZOOPLANKTON

In lakes, wetland habitats and waterbodies the zooplankton predominantly form the primary consumer organisms Most of them depend to a large extent, on various bacterioplankton and phytoplankters for food Many of the larger forms, feed on smaller zooplankton, forming secondary consumers Some of them are detritivore specialists, browsing and feeding on substrate attached organic matter, phytoplankton or concentrating on the freely suspended organic matter particles or those lying on the floor of the lakes i e on the bottom sediment The zooplankton show a high diversity and variety of forms which also show varied adaptations for such a lifestyle which in itself, is truly fascinating Many of these forms are very important fishfood organisms and also serve as food for many other aquatic macrofauna

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The zooplankton recorded during both the 1989 and 1995 surveys have been considered for description under six major groups There is also a general reference, made at the end about other miscellaneous organisms not possible to be grouped in the regular form groupings Here too, individual types have been referred to as members or more specifically as forms.

PROTOZOA

A very diverse group of unicellular organisms are found in this major zooplanktonic community Most protozoans are however not collected while sampling lake waters due to their minute size Planktonic protozoans are limited mainly to ciliate and flagellate members Sometimes, a few protozoan forms are likely to dominate in abundance, in a few habitats Such forms which can be found in abundance in some habitats could be *Difflugia, Arcella, Centropyxis* spp , etc Some of them are also found in large numbers in polluted habitats For many higher organisms in the foodchain and foodweb interlinks many protozoans form an ideal food source Many a time, based on the nutrients available, some forms are capable of specifically dominating certain habitats Even individual habitats at the same time, are capable of showing up varied diversities Most protozoans for their nutrition, depend on smaller phyto and nannoplankton A number of them are also dependent on detrital organic matter particles either suspended or settled on the floor of the waterbody

During 1989, 13 protozoan members were recorded including 4 unidentified ciliated members In the present survey during 1995, 14 forms were recorded of which, 5 members, could not be identified The most widely distributed forms were *Difflugia lobostoma* (48; 80% of lakes), *Difflugia corona* (39; 65% of lakes) and *Arcella* sp , (34; 57% of lakes) The *Centropyxis* and *Phacus* forms were recorded in 16 and 12 lakes respectively The other forms were less distributed and unidentified forms together, were recorded from 53 lakes, the maximum record for distribution

ROTIFERA

This comprises of one of the most diverse group of zooplanktonic organisms These organisms are also commonly known as 'wheeled animalcules' They possess characteristic internal radial rows of jaws serving as feeding mechanisms and in addition, possess ciliary bands and usually a foot for movement Some of them can easily get attached to substrates if necessary Most of them possess a defenite shape supported by a weak frame of exoskeleton They also show up most amazing mode of adaptations as indicated by the variety of their shapes and presence of varied external attachments (like appendages) in the different species It can be quite confidently said about plankton fauna in most aquatic habitats that, they are dominated by some form of rotifers or the other at any given time Also characteristic at most times are the seasonal and temporal variations in their abundance and population dynamics Local migrations in the habitats in relation to depth and time are also noticeable as observed from detailed studies in specific habitats over an annual cycle They are also the most important group in that they generally form the food organisms for the larger zooplankton, as well as for fish and other macrofauna in most freshwater habitats The rotifers could be both primary consumers dependant on various phytoplankton sources, or secondary consumers, feeding on smaller zooplankton mainly protozoans or even on bacteria or finely suspended organic matter The group thus forms one of the most important components in the foodchain of aquatic ecosystems

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Many members are characteristically known to be associated with polluted waters especially that of domestic effluents. Some *Brachionous* spp , are especially wellknown as bioindicators in such situations.

22 forms were recorded during 1989 The 1995 survey, showed up 29 forms of which, 2 forms could not be identified

CRUSTACEA

This group comprises of members all belonging to the well known Phylum Arthropoda This is the largest phylum in terms of species numbers, variety and among true zooplankton, hold the highest position both in terms of systematics and as secondary consumers in the food chain In healthy habitats wherein external influences of pollution are absent or at least low, a sizable population is constituted by the members of this group

CLADOCERA

An important subgroup, the 'Cladocera' includes members like *Moina, Bosmina, Daphnia* spp , being more common. They are a crucial group among zooplankton and form the most useful and nutritive group of crustaceans for higher members like fishes in the food chain. Some are specially cultured as fish food. They themselves depend on smaller zooplankton, bacterioplankton and algae as food This group is known to be highly sensitive to even low concentrations of pollutants. In such habitats therefore, a considerable drop in fish populations preferring such zooplankters as food and clean openwater habitats have been well documented. As in 1989, six cladoceran members were recorded even during 1995 also with a possibility of 3 to 4 unidentified forms However as a general observation, it seems quite clear that the distribution of these members among the lakes have been seriously affected This is evident because during 1989 this group as a whole was not represented in only about 6 of the 72 lakes surveyed. In 1995 however the scenario is that of only the 60 lakes surveyed, they are absent in 9. The *Daphnia* sp , for example had been recorded in 11 lakes during 1989 and occurs from 10 lakes during 1995. However it is to be carefully considered that even during 1995, their occurrence has been limited mainly to fairly less polluted lakes and that too in larger lakes, farther from the city

COPEPODA

This subgroup has mainly the 'Calanoid' and 'Copepoid' copepods and their nauplii. During 1989 four forms were seen which is also true during 1995 However, the overall spread seems limited now to just two forms and their nauplii *Mesocyclops* sp , was most widespread, recorded from 58 lakes and followed by the calanoid copepods found in 51 habitats. All the lakes with either of these copepods also recorded nauplii i e , among 58 lakes This is indicative that 2 lakes were so bad that they could not support even copepods or their nauplii The copepods are considered the hardiest among the larger zooplankton.

The copepods also form important food organisms for fish and are also influenced by negative environmental factors as caused by excessive human interference in lakes but to a lesser extent than the cladocerans They are much more hardier and strongly mobile than all other zooplankton, with

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their tougher exoskeleton and longer and stronger appendages. They are almost wholly carnivorous on smaller zooplankton organisms for their food needs. They can generally withstand harsher environmental conditions as compared to the cladocerans

OSTRACODA

Five forms of this subgroup could be recorded. Details of the distribution for each of the five forms have not however been recorded. These are interesting organisms and appear to have two valves (shells) as exoskeleton, somewhat like the bivalved molluscs but, are arthropods. They mainly prefer the lake bottom and mostly browse on organic matter and probably on recently settled dead planktonic organisms available on the lake floor. Thus they have a special niche and are also known to show temporal migrations through the day. They could form important food organisms for some bottom dwelling and browsing fish as well as the other host of mud dwelling organisms like annelids, nematodes, insect larvae, bottom dwelling worms and probably molluscs. It thus appears that their role in the food chain in waterbodies, is unique and special in that they can support many other organisms on which larvivorous fish like catfish, airbreathing and other fish depend to a large extent. Larger plankton being predators on them cannot also be ruled out. Their major and very important role is that they are instrumental in putting the organic detritus into the cycle of freshwater habitat energetics

MISCELLANEOUS MEMBERS

This group included other miscellaneous forms like insects, insect larvae, larvae of other animal groups like *Redia* and *Rabditis* sp , among the animal parasites etc., also have been recorded. There were 4 such forms during 1989 and 5 forms have been recorded during the 1995 survey. Most of the larvae and insects and larvae of other groups are only temporary, being plankton only during some part of their lifecycles. Similarly, free floating eggs of fish, crustaceans and other members can also form temporary plankton. All these can enter the foodchain and the foodweb ramifications of an habitat in various direct and indirect ways. Some forms like *Rabditis* spp , can provide clues to the presence of intermediary stages of potential human parasites. This is important because it is clearly indicative of direct contamination from human faeces. 6 of 72 lakes during 1989 and 5 of the 60 lakes during 1995, recorded *Rabditis* sp

GENERAL ASPECTS

In the survey of 1989, a total of 54 zooplankton were recorded with about 9 unidentified forms. During the present survey of 1995, 62 forms including 5 unidentified zooplankton have been observed

OVERALL OBSERVATIONS

PHYTOPLANKTON

Phytoplankton recorded during the two surveys of lakes in and around Bangalore as waterbird supporting wetlands. were considered under five major groups. A predominance of *Microcystis* sp , in (68%) *and Phormidium* sp , in (55%) of the lakes was followed by *Aphanizomenon*, *Anabaena*, *Oscillotaria*. *Spirulina*, *Coelosphaerium*, *Nostoc* and *Lyngbya* spp. *Microcystis sps* has shown an

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increase from 48% during 1989 to 68% during 1995.

Eleven non filamentous and twelve filamentous chlorophyceaean members were recorded. The more widely distributed forms among the former were *Coelastrum, Scenedesmus, Pediastrum, Bulbochaete and Volvox* spp. Similarly, among the latter, *Spirogyra, Microspora, Zygnema and Mougeotia* spp. were more common and to a lesser extent, *Closterium, Draparnaldia, Ulothrix and Chaetophora* spp. As compared to bluegreen algae, the distribution of the chlorophycean members is much lower. It is well known that high pollution loads are not supportive of this group and is clearly indicative of the worsening situation regarding this group's diversity. Eleven desmids as compared to ten members during 1989 were recorded with some important and potential bio-indicator members, as observed by the occurrence of these members in very few lakes. Only *Closterium* sp., is seen in 13 lakes, followed by *Gonatozygon* in 9 and *Desmidium* in 5 with rest, occurring in just one or two lakes.

The diversity of Bacillariophyceae was observed to be quite high. Compared to twelve forms in 1989, twenty four forms were observed during 1995. Most commonly occurring forms were the *Synedra* sp. in (58%), *Nitzchia* sp., (52%), *Frustulia* sp., in (37%) and *Navicula* sp., in (30%) of the lakes, with other forms being less distributed. Going by the differences in the extent of distribution of these forms, some of them are likely to serve as useful bioindicators.

Dinophyceae member (i.e., *Ceratium sp*), was recorded in very few lakes both during 1989 and 1995. It appears to be restricted to larger water bodies, not much influenced by pollution from urban or industrial sources.

In general, the high distribution of *Microcystis* sp., and *Phormidium* sp., is indicative of the widespread eutrophic situation of the lakes. A rather poor picture of diversity and abundance with regard to chlorophyceae and dinophyceae, is strongly and surely indicative of Bangalore's lakes being seriously ecologically affected and threatend for the future.

During the 1989 survey, a total of 56 phytoplankton forms were recorded from 72 lakes. During the present survey of 1995, 66 forms from 60 lakes have been observed. The detailed role of miscellaneous forms as planktonic members is less understood and needs to be attempted in future.

ZOOPLANKTON

The zooplankton recorded during both the surveys have been described under six major groups.

During 1989, 13 protozoan members and in the present survey 14 forms were recorded. The most widely distributed forms were *Difflugia lobostoma* in (80%), *Difflugia corona* (65%) and *Arcella* sp., recorded in (57%) of the lakes and to a lesser extent, *Centropyxis* and *Phacus* forms.

The Cladoceran crustaceans among zooplankton, form the most useful and nutritive group for higher members like fish and some are specially cultured as fish food. This group is known to be highly sensitive to even low concentrations of pollutants as a fall out of which, a considerable drop in fish populations preferring such zooplankters as food and clean openwater habitats have been well documented. 6 cladoceran members were recorded during both surveys. As a general observation however, it seems quite clear that the distribution of these members among the lakes have been

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seriously affected This is evident because during 1989 this group as a whole was not represented in only 6 of the 72 lakes whereas, in 1995 they were absent in 9 of only 60 lakes surveyed. Further during 1995 their occurrence has been limited mainly to fairly less polluted large lakes, farther from the city.

Among copepods four forms were seen during both the surveys. However the overall spread now seems limited to just two forms and their nauplii. *Mesocyclops* sp., was most widespread recorded from 58 lakes and followed by the calanoid copepods found in 51 habitats 2 lakes were so bad that they could not support even copepods though copepods are considered the hardiest of larger zooplankton and can generally withstand harsher environmental conditions compared to the cladocerans

Five forms of Ostracods were recorded Their major and very important role is that they are instrumental in putting the organic detritus into the cycle of freshwater habitat energetics. It is of concern to note that this group did not occur in only 4.2% of the lakes in 1989 but presently, they do not figure in 11.7%

Among the miscellaneous forms, *Rabditis* spp., provides clues to the presence of intermediary stages of potential human parasites as, it is clearly indicative of direct contamination from human faeces 6 of 72 lakes during 1989 and 5 of the 60 lakes during 1995, have shown up this form

In the survey of 1989, a total of 54 zooplankton were recorded with about 9 unidentified forms and presently, 62 forms including 5 unidentified zooplankton have been observed.

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QUALITY OF LAKE WATERS IN AND AROUND BANGALORE AND MADDUR

B.K. Chakrapani and V.R. Ramakrishna Parama

SUMMARY

Water samples from 61 lakes of Bangalore and Maddur were analysed for various physical and chemical properties with an ecological objective of evaluating the quality of water The evaluation is in light of the lakes being considered as wetland habitats with respect to their ability to support plankton other organisms and finally, the waterfowl and other birds. Except for the parameters viz., colour, pH and Dissolved oxygen (DO), all the other parameters were analysed by the Karnataka State Pollution Control Board (KSPCB) The results have been discussed, keeping the EP (act & rules), GOI [4], as a reference

The waters were found to range from neutral to alkaline in reaction with 85% of them recording an electrical conductivity of 1 0 milli mho/ cm or less All the lake waters had Oxygen dissolved in them, with a few lakes showing more Oxygen solubility The contents of dissolved solids were generally more than the suspended solids which, seem to have chiefly contributed to high alkalinity and conductivity levels

The cations were found to occur in the following order of descendance viz , Sodium > Calcium > Magnesium > Potassium. The anions were found to occur in the following decreasing order viz Bicarbonates > Carbonates > Chlorides > Sulphates > Phosphates Among the major nutrients, the total nitrogen levels were higher than the dissolved phosphates

Of the metallic ions which were analysed, Iron was found to be the most dominant and was found to be in high quantities especially in some of the larger lakes This was followed by very low quantities or traces of Zinc and only traces of Lead in some of the lakes

The results of the water quality for the lakes surveyed during 1995 have been discussed in this section

INTRODUCTION

In Karnataka. tanks[1] or in other words lakes[2], form a major source of irrigation water covering nearly 30 to 35 percent of the irrigated area In Bangalore area there were as many as 130 tanks which provided for substantial irrigation. Of late, some of these tanks have been contaminated by effluents and other pollutants emanating from the ever increasing industries, human habitations and this has posed a major problem not only in terms of maintenance of good irrigation quality but also to the existence of aquatic fauna and flora and to the human beings [1 in 2]. As of today, just the stored water quality in the existing lakes itself is very bad Further, it is already the present situation that most of the lakes in close proximity to Bangalore city today have already lost most of their irrigation

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1. Refers to a structure, created for the storage of water brought in by rain / water inflow into valley regions from catchment zones; the water body being impounded (or limited) by man made bunds (dykes) across the valley [3].

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potential except for a few very large lakes Significantly however, these lakes are that much more ecologically important for the City, as made out from the various other multifarious roles they play; as brought out in the other sections on birds, habitat status and plankton of this report

In recent years, Bangalore has seen a quantum leap in the number of industries and other sectors of a rapidly developing Metropolitan Urban area. Thus, its ever growing populace has resulted from developmental activities in terms of infrastructure addition like working places, educational institutions, and other employing organisations etc. To this can be added the residential infrastructure for the people so engaged and their transportation needs to commute. The above activities and needs have alltogether brought in continuous and rapidly increasing water and air pollution loads in Bangalore Even air pollution to a large extent can end up in water polluting end results! especially during monsoons which can be spread over more than 6 to 7 months in an year in this region apart from scattered showers during other months; cyclones on either coasts of our country also

being quite effective In Bangalore and the surrounding regions as brought out in the other sections, most of the effects of pollution irrespective of their origin, generally end up in their lakes!

The quality of the lake waters are greatly influenced by various physico-chemical parameters; natural as well as those caused by the different types of enviromental pressures facing such haats in and around fast spreading and developing cities like Bangalore. Changes or shifts in the lake water quality would definitely have significant influences on these lakes and their associated wetland habitats which, cater to a variety of species of flora and fauna including the most observable and hence important group of animals, the birds supported by these habitats as made out from the other sections

Considering the above and with a view to assess and guage the overall situation in the lakes with respect to the quality of plankton organisms and bird-life supported by these habitats, a survey of 61 lakes in and around Bangalore has been attempted One of the main objectives has also been to provide a more informative and ecologically evaluated assessment of the water quality in these immensely valuable, fragile but necessary ecosystems Their existence in the midst of densely developed urban areas, themselves facing threats from immense and varied environmental pressures, becomes especially vital Twenty two water quality criteria have been analysed and evaluated Some of the general results have also been discussed in light of the lake water criteria compared to the values from some lakes chosen as control habitats The most affected waterbodies and the most contributive pollutionary parameters have been attempted to be indicated However the 'Comparitive results' section, specifically details the comparative situations as regards the water quality scenario for 44 common lakes and 13 common water quality parameters for the sites common during the two surveys

MATERIALS AND METHODS

Water samples from 61 lakes located in the Bangalore area were collected during January 1995 and were analysed for twenty two parameters. The colour, pH (by paper) were recorded and the DO, fixed

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2. Tanks of Bangalore are referred to as lakes in this report.

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in the field itself The DO was then analysed using standard methods [5] and rest, by the KSPCB. It is to be noted here that the critical limits for various water quality parameters in relation to bird habitats per se, have not been worked out However, the results have been discussed based on the other general water quality limits, available

In order to get a clearer picture of the relationship between the various physico-chemical parameters and their possible influence on the water quality, the data was subjected to a 'cluster analysis', adopting the 'rank correlation, unweighted pair group average' method. Some more analyses of this kind are also described. The clusters of the relevant groupings can be seen in the cluster plots appended to this report

Further, a spacial distribution of some parameters with reference to area wise distribution has also been mentioned wherever it is felt interesting This gives a picture of the intensity of the presence of a specific parameter However it is to be kept in mind that the western and especially the south-western regions around Bangalore have not been well represented as far as water quality parameters are concerned since lakes from these areas being generally small or very small have not been sampled for water and plankton

RESULTS AND DISCUSSION

The results from the water quality analysis have been presented for tanks surveyed during 1995 and comparisons with the status during 1989 have also been attempted

Colour and Turbidity: Generally, lake water **colour** can provide useful clues to make a quick preliminary assessment regarding some key environmental parameters which could be influencing an aquatic ecosystem. Eutrophication from sewage or domestic waste inputs do commonly render the waters green over a period of time and is especially pronounced in the tropical regions of the world This is initiated by the occurrence of blue-green algal blooms and later on, their establishment becomes a permanent feature It is well known that such waters cannot support a good diversity of organisms Dominance from effluents other than sewage like that from industries or processing units etc , can lead to other colours like brown, reddish or black etc These waters due to the pollutant inputs also render the system unproductive and many organisms cannot survive; thus, affecting their diversity A highly disturbed shore area, devoid of vegetation can inturn combine to make the waters turbid to a large extent In eutrophic systems the plankton and other dead organic matter in high levels would contribute highly towards an autochthonic **turbidity** source [1,2]. The above situations have been and are seen in quite a number of the lakes surveyed The section on the lake status provides details regarding a generalised quantitative picture regarding these parameters

Turbidity in lakes is a highly significant parameter as far as the primary productivity levels are concerned and these two are well known to be inversely proportional Turbidity is caused mainly by the presence of solids of various origins which remain suspended in lake waters. Silt particles, organic matter, sewage and other effluents can all contribute to this factor. Organic matter derived from aquatic/ shore vegetation and their litter etc , is mainly colourless but silt or mud provides a brown or muddy colour and sewage, industrial and other effluents can bring about a murky colour change All

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these together bring about a reduction in the transparency of lake waters and retard light penetration to a large extent. Further, the turbidity introduced into lake waters would not clear up quickly because of convection, mixing and wind action [2]. The results of this parameter are also presented in the section detailing the status of the lakes surveyed

pH values: The pH values among the lakes showthat the waterswere neutral (7.0) to alkaline (9.5) in their range. A majority of the samples recorded alkaline pH, the distribution being 65.5% with pH between 7.6 - 8.5 and 18% with pH between 8.6 - 9.5. Only a small percentage of 11.47% were neutral in reaction. Of significance were the waters of Yediyur, Ulsoor and Puttenahalli lakes, which recorded a pH above 9. These were followed by C. Hulimavu & Gottigere (8.5), Hessarghatta (8.3), Kengeri (on highway) 8.2, Mantapa & Sakalvara (8.1), Arehalli, D. Hulimavu, Harohalli(s), Tavarekere and Vengaiah lakes (all 8.0). The rest of the samples recorded values less than 7.9 pH. Only 3 lakes (5.08%) showed pH values above the range permitted by the set standard limits

The pH of most natural waters fall within the range of 4 to 9. Most of the waters are slightly alkaline due to the presence of carbonates and bicarbonates. A deviation from the desirable pH range for drinking waters of 7.0 to 8.5 which is true of some lakes may be indicative of the entry of acidic or basic industrial effluents. The natural waters based on their pH values, can be divided into three distinct classes. **(a)** pH always above 8: waters contain carbonates with or without bicarbonates without any free carbonic acid; **(b)** pH ranging from 4.5 to 8: most natural waters fall under this category and **(c)** pH being 4.5 or less: these waters contain free acid in addition to carbonic acid but do not contain carbonates or bicarbonates

Most of the lake waters tested were found to belong to **a** and **b** categories. In the present urban water resources scenario and in view of the realised utility of lake waters especially for the future, the pH becomes an important parameter.

The overall pH ranged from 7 - 9.5 (urban), 5.5 - 8 (non urban) during 1995 ; from 7.3 - 8.7 and 7.5 - 10.1 during 1989 respectively. Its spatial distribution indicates a high range for urban areas.

Electrical conductivity (EC): This parameter is an indicator of the dissolved salts content. 70 % of the lake waters showed low EC with values less than 1 m mho/ cm whose chances of becoming saline or alkaline are possibly remote. As much as 21% of the waters recorded EC values between 1 & 2 m mhos/cm. Such waters are injurious to plants/ plankton especially those which are sensitive to salts

The spatial distribution for EC also clearly shows that a majority of the sites recorded EC values of 1-2 or less and here too the urban areas showed very high values and pockets of high EC in other areas. The EC values ranged from 0.4 - 3.2 (urban), 0.1 - 1.7 (non urban) during 1995 and 0.34 - 4.4 to 0.21 -0.96 respectively

An electrical conductivity of about 0.4 m mhos, is considered ideal for healthyproduction of plankton, vegetation and other organisms [1,3&6]. However, higher conductivities are not known to limit productivity [7] unless they exceed about 2-2.25 m mhos/cm. Observations associating higher production with higher conductivity are also reported [8].

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The major lakes of concern were found to be Chikka Hulimavu (3 2), Anchepalya (2 3) and Puttenahalli (2 0) The EC of above 2 m mhos/cm clearly indicate that the salt concentration is high in these tanks Such high salt concentrations would not only affect plant life in the surrounding ecosystems but would also affect adversely, the aquatic biological food chain and ecology [1,3]

Dissolved and Total suspended solids (DS & TSS): The term solids is generally applied to all matter contained in the water and these solids could be either dissolved or suspended in the water medium depending on the nature of the substance The amount and nature of these solids were found to vary considerably in the different lakes The dissolved solids consist mainly of bicarbonates, carbonates, sulphates, chlorides, nitrates and possibly phosphates of calcium, magnesium, sodium and potassium Traces of salts of iron, manganese and some other substances, could also be present

The extent of dissolution of solids have a direct bearing on the Electric conductance and this is observable clearly in the lakes Chikka Hulimavu, Anchepalya, Puttenahalli, Kalkere, Rampura, Kengeri, Nagavara, Nelamangala, Rachenahalli, Vartur, Vengiah, Bellundur, Puttenahalli (a) and Jakkur arranged in the decreasing order of their dissolved salt content The EC values recorded in some of these lakes were also found to be in the higher range of 1 0 to 3 2 m mhos/cm The overall values ranged between 26 8 to 2074 mg/l during 1995 with a range of 201 - 2074 in urban and 89 - 1113 mg/l in nonurban tanks During 1989, the ranges were much higher being from 215 04 - 2841 6 and 134 4 - 6144 mg/l respectively, the overall range being from 84 5 - 6144 mg/l

In general, levels of DS of upto 500 mg/l are most desirable and the maximum permissible limits set for domestic use is 1500 mg/l Many lakes however are shown to possess fairly high and some, very high DS levels High DS levels are also well correlated with the EC of lake waters and can have negative influences on the biological production efficiencies of lake ecosystems [7,8] and are almost similar to the effects of high electrical conductivities

The BIS (Bureau of Indian Standards) has fixed a limit of 30 mg/l for the **TSS** in waste waters, dischargeable into water courses and the EP act, GOI [4], specifies a limit of 600 mg/l for river water standards This is a very important ecological parameter, directly influencing light penetration in aquatic systems and hence the primary production efficiencies of lake plankton Both mineral and organic classes for suspended matter are possible in waterbodies Badly managed catchment zones can cause erosion and bring in large quantities of silt from rainwater runoffs and fine silt with poor settling mechanisms in lakes can lead to high SS levels over long periods of time SS of organic nature can be very high in eutrophic systems and these are mainly autochthonous and bad for production by forms other than those dominating a particular lake Organic inputs coming from well managed catchments; especially those well vegetated (wooded) or shores covered by grasses and wetland plants could be beneficial in being able to settle mineral SS faster and thus maintain lake waters clear [3] and possibly, more productive for a higher diversity of plankton High SS levels can easily deplete dissolved oxygen concentrations especially if it is of an organic nature High SS lead to high turbidities and hence may affect the feeding and therefore the occurrences of surface water feeding and diving birds like ducks and in general, the fish eating birds The section on birds may

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please be referred Abrasive SS may cause injuries to fish and their respiratory organs as well as choke them to death

The overall range for this parameter extended from 12 to 348 mg/l. Estimated only during the 1995 survey, it ranged in urban lakes from 20 - 348 and from 18 - 280 in non urban lakes Rachenahalli, Tavarekere, Manchappanahalli, Kudlu @ Rayasandra, Muthanallur and Doddatumkur lakes showed SS values higher than 240 mg/l. The shallower waterbodies appear to possess higher SS levels.

Dissolved Oxygen (DO): Oxygen can get dissolved in most lake waters in varying concentrations Solubility of oxygen, depends on many other environmental factors like temperature, pressure, wind conditions salinity of the water etc. It is one of the most essential and basic inputs for production at the primary level by microrganisms, algae or phytoplankton etc and further, to sustain organisms at all other higher levels like zooplankton, aquatic insects, worms, molluscs, fish etc. Thus, it is a highly significant parameter affecting the sustenance of organisms occupying any trophic level in an aquatic ecosystem. Its level determines whether aerobic or anaerobic organisms, carry out the biological activities in the lake system concerned and also which biological or chemical processes operate in the system

The DO concentrations were seen to range from; overall: 8 6 - 25; urban: 8.6 - 25 and nonurban: 8 6 - 18 mg/l during 1989 and the range was much lower during 1995 being 3 3 - 15 7 and 5 6 - 10 7 for the urban and nonurban lakes respectively It is to be noted that during 1989, none of the lakes were found wanting as regards the ecologically or ideally required DO levels for water bodies for normal levels of primary production. During 1995 it is seen that 33 (54.1%) lakes had less than 8 mg/l and 4(0 7%), less than 5 mg/l These levels of 5 mg/l are a critical ecologically recommended minimum for sustaining a waterbody and 8 mg/l, the recommended DO concentration for a healthy and ideally productive lake waterbody [10,10a,2&3] It is to be noted very seriously that none of the lakes surveyed during 1989 recorded DO levels less than 8 mg/l A critical minimum of 3 mg/l is fixed as the ICMR standards for piped water supply which is however, not of much ecological significance for lake waters It is still concerning that two lakes during the 1995 survey namely Kalkere (3.3) and Bellundur (with 4 mg/l) have shown up very low DO concentrations This is a very disturbing situation ecologically and the immediate means to remedy the situation needs to be looked into.

Regarding urban lakes however, it is important to look upon additional perspectives to understand the dynamics of DO levels In 1989 39(50%), 11(14%) and 3(4%) lakes showed above 10, 15 and 20 mg/l of DO respectively During 1995 however, the trends had 8(13%) and 1(1.6%) of the lakes with more than 10 and 15 mg/l of DO respectively.

In 1989 most of the tanks recording more than 14 mg/l had been observed to support blue green algal blooms even during a cold month like January with 4% lakes recording DO even above 20mg/l and some as indicated earlier, more than 15 mg/l during both the surveys However, the point of significance to note is that such high concentrations in the tropics could be dubious or misleading ecologically if, only the surface water DO levels are considered for any ecological evaluation. High DO concentrations at the surface are due to releases from photosynthetic activity [2,10&10a] Waters at lower levels would thus be depleted of DO which would then support only a very limited variety of

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aquatic organisms Such waters are proven to be of highly doubtful quality in terms of potability Surfactants have the property of bringing down the DO levels drastically at least in pockets where washing is common or frequent It is to be noted that lakes or waterbodies with with very low DO, can hardly support diverse populations of aquatic fauna and flora [2] Yediyur, Ulsoor, Puttenahalli, Lalbagh, Sankey, Harohalli Hessarghatta, Hirekere and Nelamangala lakes recorded more than 10 mg/l of DO Ulsoor and Yediyur lakes showed highest DO levels of almost 15 mg/l

Alkalinity and Hardness: Alkalinity in waters of natural or manmade lakes is normally due to the presence of bicarbonates, carbonates and the hydroxylated compounds of calcium, magnesium, sodium and potassium However hydroxide salts are generally present in very low levels Because of the relative abundance of carbonates and the availability of CO_2 that enters into equilibrium with them in an aqueous solution, most waters contain bicarbonates and carbonates only However the occurrence of hydroxide ions in neutral waters are rare The Phenolpthalein alkalinity(PA) indicates the presence of carbonates, bicarbonates and hydroxides whereas, Total alkalinity(TA) would indicate the exact extent of alkalinity in terms of $CaCO_3$ in mg/l

The results indicate that 43% of the sites did not have PA 11% of the sites recording a pH of above 8 5 have shown PA levels higher than 210 mg/l However, the Rachenahalli and Tavarakere lakes have recorded 348 and 310 mg/l of PA but show a pH of 9 1 and 7 4 respectively thereby indicating that the alkalinities in these lakes are caused by different salts An overall range of 0 - 135 6 mg/l PA has been recorded and seen to be more in urban lakes

TA is a parameter closely associated with PA The Puttenahalli (b) waters recorded the highest TA of 728 mg/l which also had a correspondingly high pH of 9 1 and also the highest PA of 135 6 mg/l which indicates deposition of carbonates or bicarbonates Some other lakes with high alkalinity were Kengeri, Kalkere, Varthur, Ancheplaya, Nagavara, Agara, Bellundur and Madivala These lakes also recorded in general, a pH of more than 7 5 except Anchepalya It was also surprising to observe that C Hulimavu lake recorded low alkalinity values despite it recording high pH and EC values

Hardness in lake waters is predominantly accounted for by the carbonate and bicarbonate contents These were found to be high in all those lakes which recorded high TA and further, found to be fairly high or highly alkaline in their pH values The ten lakes in their decreasing order of **Bicarbonate** values were Puttenahalli(b), Agara, Bellundur, Madivala, Varthur, Nagavara, Kalkere, Anchepalya, Puttenahalli(a) and Nelamangala Similarly, ten lakes with their highest **Carbonate** values were Puttenahalli(b), Kalkere, T G halli, Ulsoor, Anchepalya, Vengaiah, Sankey, Gopalpura, Lalbagh and Nagavara

It needs to be considered that the situation at Puttenahalli lake be seriously viewed since it has a high alkaline pH, EC, DS, TA as well as substantial quantities of carbonates and bicarbonates, dissolved in it Further it is to be seriously noted that all lakes surveyed during 1995 are categorised as hard, since they exceed 50 mg/l of CaCO3 concentration [9]

Chlorides: This is a common ion found in lake waters was found to be high in the lakes C Hulimavu, Kalkere, Anchepalya, Rampura, Jakkur, Yellemallappachetty, Rachenahalli and Putenahalli These

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values do suggest that these lakes could be receiving substantial contamination from domestic sewage and industrial effluents Sewage inputs into these lakes were seen to be true during the physical survey Chlorides are associated predominantly with Ca, Mg, Na and K cations and high values can cause ecologically serious problems

A close relationship appears to exist between dissolved salts (combined result of carbonates, bicarbonates and dissolved chlorides) and conductivity

Sulphates: This anion is seen to be on the lower side as far as the ranges of other anions analysed for, in the lakes are concerned. Not analysed during 1989, it was found to range from 8 - 68 and from 3.6 - 22 mg/l in the urban and nonurban lakes respectively. Vengaiah and Bidarekere lakes recorded the highest and lowest values A very conspicuous result is that of the Vengaiah lake where there has been an accumulation above 200 mg/l This is highly ecologically undesirable Even the standards fixed for this parameter are 50 mg/l

Sulphates are generally known to occur naturally in waters as a result of leaching from gypsum and other common minerals In urban areas especially, several treatment processes for use of water for domestic or industrial utilities like addition of alum and production of effluents let out from different types of chemical, process and other industries could cause increases in the sulphate contents Another very important source could be from domestic wastes carrying wash waters resultant of the generally heavy use of detergents and similar washing and cleaning agents However their contents could also vary widely.

Sulphates also contribute to the total solids content and are of considerable importance since they can impart a bitter taste and undesirable odour to the water. Sulphates are also reduced under anaerobic conditions to hydrogen sulphide, causing a very foul odour. It is significant in the context of preserving our lake quality to note that sulphides are common constituents of many industrial wastes as well as sewage Lakes recording higher values of sulphates could be getting contaminated by such wastes especially when these are untreated or insufficiently treated

Phosphates: Phosphorus is of great biological significance [3]. However, the contents of phosphates in the lakes surveyed were found to be in very low levels. The trace level at the analysis stage itself has been set at 0 1 mg/l which makes it quite difficult to assess the situation in the lakes. The standard is fixed at 0.2 mg/l and this is seen to be 0 2 mg/l for Nagavara and 0.5 mg/l for the Madivala lake. Only in 13 lakes, this parameter is not recorded and naturally in most (42 or 73 7%) of the lakes surveyed it is found to be in traces i e , 0 1 mg/l Though found to be at these levels, this parameter is very crucial and ecologically elusive as it has a tendency to 'hit the sink' i e., this parameter gets easily precipitated by many cations occurring in lakes and accumulates at the lake bottoms becoming temporarily inaccessible to productive organisms (the phytoplankton) When accidentally the lake bottoms get disturbed, this parameter gets released and can lead to sudden blooms especially of bluegreen algae in eutrophic lakes where, phosphate accummulations are well known In the alternative, phosphate additions are immediately used up by algae where also, low levels of this anion get recorded Therefore the levels of this parameter needs to be considered in light of its unpredictability. It is also well known that its biochemical and geochemical behaviour is quite complex

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Nitrogen: This parameter was estimated as total nitrogen. It was found to range from 0 0 in just one lake to a very high level of 3.2 mg/l in view of the standard level fixed at 0 1 mg/l. 39 lakes (68 4%) were found to possess nitrogen higher than the permitted limit. This parameter is very significant from the point of view of algal productivity in lakes and is of special significance in urban lakes where excess nitrogen levels can lead to undesirable algal blooms. Further the level of nitrates, toxic to aquatic animals is not well worked out [11] but natural waters containing less than 4 2 mg/l are believed to support fish populations [12]. A few lakes among those surveyed appear to be coming closer to this level and this fact itself should be concerning enough. These aspects have been covered in detail in the plankton section.

It however suffices to consider that the concentrations of this nutrient are generally existing in levels far from that which is ecologically preferable.

Cations: A comparison of the contents of the cations analysed for in the lakes, showed that they are present in the decreasing order of Sodium, Calcium, Magnesium and Potassium. This order of occurrence seems to be supported by the fact that most waters had an alkaline pH. Their contents were however not found to be occurring in alarming proportions.

These cations do not cause adverse effects in water but in the form of carbonates, bicarbonates or as chlorides and sulphates in high concentrations above 500 mg/l, could cause ecological problems.

Heavy metals: the analysis of the lake waters indicated that among the heavy metals such as *Iron, Zinc and Lead* **Iron** was seen to be present in higher quantities and the other two in traces. Iron usually exists in natural waters both in its ferrous and ferric forms. The form of iron occurring at any given time can however get altered as a result of oxidation or reduction or due to the growth of bacteria in the sample, during storage before analysis. Usually the ferric form is predominant in most of the natural waters. Iron in water may be either in true solution or in colloidal state or in the form of relatively coarse suspended particles. Iron imparts a bitter sweet astringent taste to water which is detectable at very low concentrations. Its content upto 0.3 mg/l is considered as the permissible for drinking water. When industrial effluents containing iron are discharged into a water body, iron reacts with the natural alkalinity of the waters and precipitates as ferric hydroxide which blankets the stream or lakebed and has a most objectionable appearance.

The waters of Tavarekere, Doddasanne, Madurekere, Manchappanahalli, Kudlu and Sakalvara had recorded iron above 10mg/l. About 12 tanks have Iron 0 2 mg/l or less. Iron is present in quantities higher than 0.5 mg/l in over 85% of the tanks. The content of **Lead** and **Zinc** were observed to be only in traces.

CONCLUSION

Considering the various physico-chemical parameters tested for, from a very broad perspective, it is felt that of the 61 lakes surveyed, some of the lakes could be of immediate concern from the point of view of their unsuitability or threatened status in as far as their ability to sustain even a fairly healthy level of biological activity and a reasonable level of biodiversity. It can be considered that they are not

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able to sustain the different trophic levels in an ecologically efficient manner Some of them however, can be considered to be seriously ecologically threatened Such of these most likely lakes, based on the data available are Anchepalya, Bellandur Chikka Hulimavu, Harohalli, Kengeri (along highway), Kalkere, Nagavara, Nelamangala, Puttenahalli, Rachenahalli, Rampura, Tavarekere, Ulsoor, Varthur, Vengaiah, Yellchehalli and Yellamallappachetty

The rest of the lakes as per the water quality criteria are concerned, can be considered fairly safe as far as sustaining aquatic fauna and flora However, even these water bodies especially those located in the urban (built up zone) and those, fringing the urban zone need immediate protective action and must be rapidly followed up with ecologically based conservation and development efforts The non urban lakes also need to be protected immediately and measures to conserve and ecologically improve them however could possibly be carried out in a less intensive manner with a long term approach For either category of habitats it is very important to have a strictly ecofriendly approach so that intensive artificial developments could be avoided

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PLANKTON AND WATER QUALITY OF LAKES IN AND AROUND BANGALORE: COMPARISONS BETWEEN 1989 AND 1995

B. K. Chakrapani

INTRODUCTION

In this chapter, an attempt is made to compare the results and inferences of the 1989 and 1995 surveys pertaining to water quality and the plankton community. Wherever the situations appear to be very alarming, informative or relevant, the same have been briefly discussed.

Presently, it is of utmost importance that a futuristic and environmentally sound approach be followed or developed to ensure the ecological well being, existence and sustenance of natures' naturally occurring and evolved gifts or man made habitats like lakes These have now been ecologically nurtured, turned over time and can be considered to have evolved, only when historical records of ecological changes/ successions are available to even realise whether changes have occurred or not

Such an input to guage changes should actually come from systematically recorded and documented information drawn from monitoring works/studies, maintained from time to time. This vital issue is fairly well accepted scientifically However it is yet to see conviction as a real scientific thrust area and most important, in governmental and administrative parlance, as an area of vital ecological need Encouragement for study or documentation of such nature is really poor in the area of wetland lake habitats though the needs for their protection, preservation, conservation, improvement etc , have been realised only recently as being very significant in the context of waterbodies scattered among urban expanses especially endowed with topographic features as observed for the Bangalore region [1] General information on the development of lakes in this region, their ecological importance, present status etc., have been covered in the status and bird sections of this report These lakes have had immense value when one considers many aspects like agriculture and irrigation; as a drinking and domestic water resource; for aesthetic and cultural values; in supporting vegetation, good climate as well as to providing support for generation of food resources like fish etc. [1]

These lakes however are being faced with many ecological threats as made out from [1,4,5&10] This situation naturally affects the lake water quality [6,1] and percolates down to lower trophic levels for ex., the plankton communities [12,1&5] Plankton biodiversity is being severely threatened [12] Interesting relationships can also emerge between lower and higher trophic levels like plankton and birds [11].

Considering Bangalore city with its lakes spread in and around it [1] in the present day context amidst rapid expansion, development and industrialisation, existence of the numerous freshwater habitats are found to be seriously threatened Rapid urbanisation has lead to loss of wetland habitats or their mutilation through bad or no management whatsoever, encroachment, unregulated mudlifting, pollution from sewage and industrial effluents and dumping of wastes and litter etc , [5,4,1 & 10] Increasing pressures of change in landuse for non-agricultural and urban development activities are now, clearly evident [12].

The above situation has been seriously gauged and thereafter, has been well stated in [4] 1986 that in

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view of 'expanding roads and vehicular traffic, water sheets and trees become valuable assets to improve the health and quality of life for Bangalore's residents' Lakes incidentally can provide both these assets. Further, wise use of wetlands is advocated by many people, but lack of knowledge causes too many losses of values which could easily be incorporated [7] However, to realise and understand these values it becomes very necessary to build the necessary information so that the values could be restored and realised at least in the future (immediate future) for an environmentally stressed city like Bangalore

'However, efforts towards ecologically sound management, have neither been able to be comprehended at the right time, nor have they kept pace with the demands provided by recent gains in knowledge and concepts of ecologically oriented habitat conservation efforts' [5] Ecologically sound efforts can be ideally developed from a well documented data base covering the past, existing status as well as continued monitoring for the future.

It is therefore stressed in this section that such information is of vital importance for even formulating evolving, planning or taking any ecologically sound decisions for development, management, or implementation It is strongly felt and feared that without such vital information on a timescale being used as a base, only experimental efforts would result which would naturally not be based on previous data, information, experience or scientific conviction. The drawback of such efforts is that they cannot be used as predictable models though they may generate very positive ecological results more as chance occurrences But for real ecological gains in any man managed system, a predictable, scientifically and conceptually developed model would be dependable and have easy replicability and acceptability

It is in the above context that this chapter has relied on available documentation and information brought out mainly through the humble voluntary efforts from birdwatchers of Bangalore during the lake surveys of 1989 and 1995 along with the welcome governmental support mainly in terms of logistics It is hoped that the inferences drawn from the comparisons of the results documented from the two surveys serving as the timescale for the present, would serve to some extent the needs thought out in the approach mentioned above.

METHODOLOGY

Of the 88 sites covered during the two surveys, 43 lakes were common for observations on the Plankton community and 44 lakes for water quality considerations. The data for 1989 has been drawn from [1] and for 1995, from the present report. These common lakes considered for comparison include 20 urban lakes (including Sankey lake as the control) and 24 nonurban lakes with some waterbodies in the Bannerghatta National park and the T G. Halli lakes, serving as controls for the water quality criteria These controls are excluded from the 24 lakes, not having been surveyed during 1989 The controls have been decided based on three major considerations viz., their; (i) close location, easy accessibility with a high local relavence, (ii) possibility of being least ecologically affected in future and (iii) the immediate assurability of their long standing existence. Incidentally lakes of Bangalore are already under the Forest dept , for protection and management [2].

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These lakes have been compared with respect to each of the thirteen common parameters which in turn, have been compared; with respect to (a) values between the two time periods, (b) values / ranges of the control lakes and (c) values / ranges with respect to [3]. The frequencies of these comparisons were used to shortlist the most affected lakes (from both the positive and negative perspectives). For these lakes finally, the information status with regard to water quality as well as changes or shifts if any with respect to the plankton community has been attempted to be inferred

General observations keeping the overall situation as seen at all the sites covered during the two surveys have also been brought out to give an idea about major trends if any. Of course, comparative information drawn from common sites do provide the most interesting/useful inferences and this has been achieved to some detail. For the shortlisted lakes a brief individual account is also provided

RESULTS OF COMPARISONS

WATER QUALITY

There were 19 urban and 24 nonurban lakes which were common to the two surveys carried out during 1989 and 1995. These lakes have been considered for the comparisons in this section. Further, only 13 water quality parameters were common to both the surveys and 8 more parameters were analysed for the 1995 survey only

URBAN LAKES

Overall, of the 19 urban tanks, the results of 1995 survey for water quality criteria have shown considerable increases in more than half (i.e , in 10 and more lakes) in their levels, compared to the levels which existed in 1989. These parameters (i.e. 8 of the 13) were found to be Bicarbonates, Carbonates, Chlorides, Sodium, Iron; with Magnesium, Zinc and Potassium levels being much higher. The differences were much lower for pH, conductivity, diss. solids, diss. oxygen and calcium. Compared to the control values (i.e, of Sankey lake), the parameters viz., pH, chlorides, calcium, iron and zinc (i.e only 5 of the 13) were higher for 10 and more lakes. For the 1995 survey there were 21 parameters. Of these, only 6 parameters namely calcium, potassium, total alkalinity, hardness, sulphates and total nitrogen were found to be higher in 10 and more of the 19 lakes considered for comparison against the urban control (Sankey lake) levels

Considering all the parameters together, the urban lakes which have shown serious changes for more than half i.e. (6 and more of the 13 common water quality criteria) for 1995 values as against 1989, were found to be Anchepalya, C. Hulimavu, D. Begur, Jakkur, Kalkere, Lalbagh, Madivala, Nelamangala, Puttenahalli, Rachenahalli, Ulsoor, Yelahanka and Yellemallappachetty. Among these, the most seriously affected are Anchepalya, C. Hulimavu, Kalkere, Nelamangala, Puttenahalli and Ulsoor. Apart from these, the less affected lakes are seen to be Agara, Nagavara, Rampura, Varthur and Yediyur with Sankey acting as the control.

It is of very critical significance that considering the water parameters of 1995 levels compared against the controls, it is observed that only 5 of the 19 urban lakes common to the the two surveys, have not shown a notable increase in the levels water quality (i.e. 10 or more of the 21) parameters. The lakes which have not been so worse off were D. Begur, Jakkur, Lalbagh, Yelahanka and

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Rampura.

NON-URBAN LAKES

24 lakes located in non urban and generally rural areas were found to be common during both the surveys. Comparing for the common water quality parameters between the two surveys, it was found that the levels of bicarbonates, chlorides, sodium, magnesium, potassium, iron and zinc (i e , 7 of the 13 parameters) were higher in 1995 than in 1989 among more than half i.e , 12 or more lakes. This was true for the urban lakes also except for the carbonates. Magnesium, Iron and Zinc showed an increase of higher levels. The parameters which showed up most conspicuously for 1989 values against controls, were DO with chlorides, magnesium and zinc showing increases in most of the lakes. However, for the comparison of 1995 values against the control levels, only 7 of the 21 parameters were seen to show up higher levels in more than half i.e., 12 or more of the lakes. The parameters were DO, chlorides, magnesium, sulphates in a few lakes and for sodium, TSS and hardness for most of these lakes.

The non-urban lakes which have shown changes over the two survey periods as well as for their comparisons over the control levels, 12 lakes have shown changes for more than 7 of the 13 parameters while considering 1995 with 1989 levels. These are Anneshwara, Bidare kere, Harohalli-S, Hoskote, Jigani, Kudlu @ Rayasandra, Mantapa, Mugbala, Sakalvara, Taralu, Tattaguppe and Yelchehalli. These are therefore the most affected lakes. 8 other lakes namely Arehalli, Budigere ammani, Dodda Tumkur, Gopalapura, Gummanahalli, Kaikondanahalli, Madhurekere and Manchappanahalli lakes were affected to a lesser extent. Ardeshanahalli, Bande-kodigenahalli, Chikkajala and Doddasanne, were the 4 lakes which did not show any changes in comparisons for the water quality criteria. For the comparisons of 1995 against controls, the lakes which showed increases in 10 or more of the 21 parameters were Harohalli-S, Mugbala, Dodda Tumkur and Gopalapura (i e., in only 4 of the 24 lakes), considered

CONCLUSION

Based on the water quality criteria, it can thus be seen that among the 19 urban lakes compared, most of them (13) are seriously affected; 5 of them are less seriously affected and only 1 lake, D Hulimavu is negligibly affected. However, while comparing the 1995 levels against the control levels, only 5 of the 19 lakes namely D Begur, Jakkur, Lalbagh, Yelahanka and Rampura have shown increased levels in less than half (i.e, 10) of the 21 parameters. The above results point to rather serious levels of deterioration in the water quality standards considering comparisons between both the surveys as well as, when compared against the controls. Similarly, 12 of the 24 non-urban lakes have been seriously affected while considering the water quality situation. These are Anneshwara Bidare kere, Harohalli-S, Hoskote, Jigani, Kudlu @ Rayasandra, Mantapa, Sakalvara, Taralu, Tattaguppe, Doddatumkur and Gopalapura.

Considering the water quality parameters as such, generally the waters ranged from neutral to alkaline in reaction, with fairly high levels of electrical conductivity especially more so for urban lakes; the range being however higher during 1995. All the lake waters possessed DO with a few lakes

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especially the eutrophic ones, having much higher levels. The range in the eutrophic lakes during 1989 were seen to be higher than in 1995. Dissolved solids contents' range was markedly higher during 1989 and were generally higher than the suspended solids in most lakes during 1995 , thereby contributing to high alkalinity and conductivity levels. The following cations occurred during 1995 in their descending order for their 'minimum-maximum ranges viz., Sodium> Magnesium> Calcium> Potassium and in 1989, the order was very high Sodium> Magnesium> Potassium> Calcium. The anion ranges were found to occur in the following decreasing order viz , Chlorides> Bicarbonates> Carbonates> Sulphates during both the surveys except for Sulphates, not analysed during 1989. Among the major nutrients, the total nitrogen levels were higher than the dissolved phosphates but these were analysed only during 1995. Of the metallic ions which were analysed, Iron was found to be the most dominant, found generally in higher quantities in larger lakes, being much higher than Zinc during both the surveys. Only traces of lead have been recorded in some of the lakes generally closer to the city.

PLANKTON

GENERAL OVERVIEW AND TRENDS

For the **Phytoplankton** (PP), during the 1989 survey, a total of 56 phytoplankton forms were recorded from 72 lakes and during 1995, 66 forms from 60 lakes have been observed. Among **Zooplankton** (ZP), a total of 54 zooplankton with about 9 unidentified forms were recorded during 1989 and presently, 62 forms including 5 unidentified zooplankton have been observed.

An idea about the shifts in the class groups based on the form diversity for phytoplankton and zooplankton during the two surveys for the common lakes were compared for their trends. Seven classes were considered for grouping the number of plankton forms which occurred in each class with respect to the lakes surveyed. The class groupings were for containing 1-5, 6-10, 11-15, 16-20, 21-25, 26-30 and > than 30 forms of either plankton in the surveyed lakes. The number of lakes showing up in each of the classes was computed thereafter and the trends of these values for the two surveys have been compared.

The **trends** have clearly shown that during the 1995 survey, fewer lakes have shown higher plankton form diversities as compared to 1989. For example, 8 34% of lakes had 26-30 PP forms in 1989 but this dropped to just 1 7% in 1995. Continuing in the trend of lowering form diversities in larger number of lakes is shown for example, in the 16-20 (21 to 13%), 11-15 (33 to 30%) and 6-10 (22 to 20%) class groups for PP where also, there is a drop in the percentage of lakes during 1995 compared to 1989. A marginal increase is seen in the 21-25 class group (11 to 13%) but a dramatic increase is seen in the very low diversity class group of 1-5 forms (4 to 22%). This clearly shows that for PP, there has been an increasing trend towards a larger number of lakes slowly loosing their form diversity in terms of species richness. However, the 11-15 class group in both the surveys was dominant with the highest percentage of lakes (30-33%), supporting just 11-15 phytoplankton forms.

A similar trend is reflected among Zooplankton. For example 6 lakes (8.3%) showed more than 31 zooplankton forms in 1989 but none in 1995. A very serious decreasing trend in the 26-30 (22 to 5%)

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and 21-25 (33 to 20%) class groups was observed An increase is however seen in the class groups with very low ZP forms i e., in the 16-20 (24 to 35%), 11-15 (10 to 28%), 6-10 (3 to 5%) and 1-5 (0 to 7%) This clearly indicates a seriously decreasing trend in the form diversities of ZP in the lakes in and around Bangalore. It is to be noted that this has occurred over a short time period of just 6 years Further, it is a very serious trend that the class group of dominance during 1989 (of 21-25 forms), has shifted towards class groups with lower ZP forms i e, the 16-20 and 11-15 classes

Phytoplankton: Among blue green algae, a predominance of *Microcystis* sp., in (68%) *and Phormidium* sp., in (55%) of the lakes was observed during 1995 *Microcystis sps.*, has shown an increase from 48% during 1989 to 68% during 1995

34 Chlorophycean members including Eleven non filamentous, twelve filamentous and two unidentified members, excluding the Diatoms were recorded during the 1995 survey whereas during 1989, 33 members had been recorded The more widely distributed nonfilamentous forms were *Coelastrum, Scenedesmus, Pediastrum, Bulbochaete, and Volvox* spp ; the common filamentous forms being *Spirogyra, Microspora, Zygnema and Mougeotia* spp., and to a lesser extent, *Closterium, Draparnaldia, Ulothrix and Chaetophora* spp Compared to bluegreen algae, the distribution of chlorophycean members is much lower, high pollution loads being are not supportive of this group as clearly indicated by the worsening situation regarding this group's diversity among more lakes Eleven desmids compared to ten members during 1989 were recorded but, in very few lakes viz., *Closterium* sp , in 13 lakes, *Gonatozygon* in 9 and *Desmidium* in 5 with others seen in just one or two lakes.

The diversity of Diatoms was observed to be quite high in the 1995 survey, with twenty four forms being observed compared to just twelve forms recorded in 1989. Most commonly occurring forms were the *Synedra* sp in (58%), *Nitzchia* sp , (52%), *Frustulia* sp , in (37%) and *Navicula* sp , in (30%) of the lakes Going by the differences in the extent of distribution of these forms, some of them are likely to serve as useful bioindicators. Dinophyceae (i.e., *Ceratium sp*), was recorded in very few lakes both during 1989 and 1995 appearing to be restricted to larger water bodies, not influenced by pollution.

The high distribution of *Microcystis* sp , and *Phormidium* sp , is generally indicative of widespread eutrophic situation of the lakes and a rather poor picture of diversity and abundance with regard to chlorophyceae and dinophyceae and is a sure pointer of Bangalore's lakes being seriously ecologically affected and threatened

Zooplankton: During 1989, 13 protozoan members and in 1995, 14 forms were recorded. The most widely distributed forms were *Difflugia lobostoma* (80%), *Difflugia corona* (65%) and *Arcella* sp , recorded in (57%) of the lakes.

The Cladoceran crustaceans among zooplankton, form the most useful and nutritive group at higher trophic levels This group is known to be highly sensitive to even low concentrations of pollutants which can result in a considerable drop in fish populations preferring such zooplankters as food and clean openwater habitats Six cladoceran members were recorded during both surveys. Generally it is observed that the distribution of these members among the lakes has been seriously affected. This is

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clearly evident because during 1989 this group was not seen only in 6 of the 72 lakes whereas, in 1995 they were absent in 9 of just 60 lakes surveyed. Also, during 1995 their occurrence has been limited mainly to fairly less polluted large lakes, farther from the city.

Four forms of copepods were seen during both the surveys. The overall spread however, seems presently limited to just two forms and their nauplii. *Mesocyclops* spp., was most widespread, recorded from 58 lakes followed by the calanoid copepods found in 51 habitats. 2 lakes were so bad that they could not support even copepods which are considered to be the hardiest of larger zooplankton.

Ostracods play a very important role in cycling the organic detritus in freshwater habitat energetics. Four forms were recorded but, it is of concern to note that this group did not occur in 11.7% of the lakes in 1995 whereas they did not occur in only 4.2% of the lakes during 1989. The presence of *Rabditis* spp., provides clues to the presence of intermediary stages of potential human parasites and this is clearly indicative of direct contamination from human faeces. 6 of 72 lakes during 1989 and 5 of the 60 lakes during 1995 have recorded this form.

PLANKTON STATUS IN SOME LAKES

Among the lakes common during the two surveys, some among the urban and non-urban regions have been shortlisted based on the situations of the water quality status in these lakes. It is emphasised in this context here that the lakes with the worst changes in their water quality comparisons are necessarily being considered here. The situation with regard to the plankton members in some of these most critically affected lakes going by their water quality criteria and changes if any for the time period between the two surveys is brought out briefly. It has so happened in some lakes that the PP forms have shown decreases but most of the increases in urban lakes and some non-urban lakes showing pressures of development and increasing domestic sources of water pollution, have been in the addition or shifts in the blue green algal forms. Such situations are more indicative of pollutionary influences rather than an inference, indicative of increase in species richness.

URBAN LAKES

Anchepalya: 1995 showed an increase in PP (11 to 15). *Microcystis* spp., added; *Lyngbya* spp., not recorded; Increase in nonfilamentous algae, desmids and diatoms. ZP also increased from 17 to 22 forms. Protozoan forms did not show much change. Increase in rotiferan forms seen with a decrease in ostracod and copepod forms. Change only with respect to PP, positive.

Chikka Hulimavu: Situation worse in 1995. PP decreased from 20 to 10 and ZP from 26 to 16 forms. Some new myxophyceae members seen along with decrease in all other algal groups. Among ZP, decrease seen in all the groups with a non-occurrence of calanoid copepods. Situation has worsened.

Dodda Begur: Notable decreases in PP from 22 to 19 forms ZP from 31 to 24 forms observed from 1989 to 95. Changes in bluegreen members seen along with absence of desmids and increase of diatoms. Not much changes seen among protozoans; decrease in rotifers, ostracods and copepods observed. Going by the number and nature of forms, the changes appear to be negative.

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Jakkur: Marginal increase in PP from 9 to 10 forms but a marked decrease in ZP from 22 to 12 forms observed However, 1995 shows up a lot of bluegreen algal introductions along with a decrease in diatom forms. Among ZP, all groups have shown decreases in members except for the addition of conchostracan members. The situation is quite serious with respect to both PP and ZP.

Kalkere: Increase in PP from 13 to 15 forms for 95. A decrease is seen in bluegreen and nonfilamentous green algae. Increases seen for filamentous green algae, desmids and diatoms. However the ZP have decreased from 23 to a poor 13 members only Diversity among rotifers has been mainly lost Situation is bad for ZP and replacement by some bluegreen algae is not a good trend among PP

Lalbagh: This is an interesting lake for the plankton trends. 1995 shows an increase in PP from 12 to 20 forms Bluegreen forms seem to be on the decline along with changes for the good (increases) among the chlorophyceae, desmids and diatoms. Among ZP, no changes in absolute form numbers is seen but the quality does show changes Ostracods have not been recorded but conchostracans, added; protozoans and rotifers have increased. The situation points towards a marginal improvement. Bluegreen algal dominance has dropped

Madivala: 1989 showed a better diversity for both PP (23>11) and ZP (28>19) forms Bluegreen algae have reduced in forms but dominance is shifted to *Spirulina* spp.,and a general decrease in all other groups is observed Among ZP, a decrease in all groups except protozoans is noticed Situation has worsened over the time between two surveys

Nelamangala: For PP, 1995 shows higher number of forms (30>15) Notable changes in terms of additions of forms are seen for all the PP groups For ZP, 1989 showed marginally higher number of forms (27>24) The most notable change has been observed in the reduced number of copepodan forms. Considering plankton as criteria the lake has not shown any drastic negative changes

Puttenahalli: The number of PP have remained same at 16 However, additons and delitions have been mainly among green algae ZP have appreciably decreased from 33 to 13 forms from 89 to 95 The decrease has been phenomenal among rotifers, cladocerans, copepods and ostracods. The situation appears to be serious, showing up clearly among ZP.

Rachenahalli: 1989 showed more PP (11>6) as well as ZP (17>16) forms. Changes in bluegreen algal forms seen and decreases in other algal groups also observed. Protozoans showed an increase and rotifers, a remarkable decrease in 1995 The lake is however worsening going by the habitat status information

Ulsoor: This lake indicates a very poor picture for 1995 with a decrease from 14 to 5 forms The PP shows decrease in forms for all groups. The ZP however seem to have improved from 6 forms in 1989 to 19 presently. All groups of ZP have shown additons in general However, the situation appears to have marginally worsened (since chlorophycean members are seen to have lost representation) or remained the same since 1989

Yelahanka: Negative changes are remarkably noticeable in this lake PP have decreased from 27 to a poor 8 and ZP from 27 to 19 PP have shown less forms in all groups and among the ZP, all groups

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except rotifers and conchostracans, have also shown up decreases. Changes for the worse appear to be serious in this lake for both PP and ZP.

Yellemallappa Chetty: Between 1989 and 1995, the PP have decreased from 20 to 9 but, the ZP have shown a marginal rise from 20 to 24 forms. An increase in bluegreen algal forms inspite of improvement in other groups is worrying from the pollutionary angle. Among ZP, nothing appears to be specially indicative. PP wise the situation is still bad.

Some other urban lakes affected in a moderate way by water quality have been Agara, Nagavara, Rampura, Varthur and Yediyur. Sankey as the control lake has also shown up deterioration with a decrease in PP from 17 to 12 and in ZP, from 19 to 14 forms. A decrease has been observed in all the groups of PP as well as ZP.

NON-URBAN LAKES

Anneshwara: 1995 has shown up a marginal improvement over 1989 as seen from 9 to 14 forms and 25 to 28 forms of PP and ZP, respectively. Prospects for improvement of the lake ecologically are good. Improvements may take place fast if suitable measures are taken early, as increases in all the planktonic groups have been observed.

Bidare kere: A marginal decrease in the planktonic forms are seen in both PP (27 to 25) and ZP (26 to 25). A marginal increase in bluegreen algae however, is also seen. Situation is not very bad but, going by water quality situation and increase in bluegreen algal forms, ecological measures to improve the lake soon, may help for its early conservation.

Harohalli-S: Changes for the worse are seen to be serious. The PP forms have dropped from 15 to 4 and ZP, from 24 to 11 forms during 1989 to 1995. Changes in bluegreen algal composition and decrease in all other PP groups are seen. Among ZP too, a decreased diversity in all the groups is seen. Water quality changes are also seen to have worsened.

Hoskote: This is a large lake. The forms are seen to have marginally increased in 1995 from 10 to 14 for PP and 20 to 22 forms for ZP. Myxophyceae have shown a decrease. For the present, this lake does not not appear to be seriously affected considering the water quality criteria.

Jigani: The PP have decreased from 16 to 12 forms but the ZP have shown an increase from 14 to a fairly high 24 forms. A shift in bluegreen algal composition with the recording of *Microcystis* spp., additionally and an increase in *Brachionus* spp , is indicative of pollutionary influences. The lake is thus to be suitably protected for ecological improvement.

Mantapa: There is a noticeable decrease in the PP (27 to 19) and ZP (31 to 17) forms between the two surveys. There is no increase in bluegreen algal forms but a decrease in the other PP groups and all the ZP groups which is indicative of a worsening situation. To some extent, this is reflected in the deteriorated condition in the water quality.

Mugbala: This lake also reflects decreasing form diversity trends for both PP (15 to 7) and ZP (26 to 16) during the period from 1989 to 1995. A decrease in bluegreen algal forms is encouraging. However, a drop in form diversities in all other groups of PP and all ZP groups, is indicative of a

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worsening situation.

Sakalvara: This lake shows up a fairly drastic reduction in forms in all the groups of PP as well as ZP except for an increase in miscellaneous forms of ZP during 1995 The diversity has dropped from 28 to 4 (PP) and 34 to 12 (ZP) It does appear that there are serious pressures in operation, affecting plankton diversities Ecological measures are it appears, very urgently needed.

Taralu: This lake also shows a decrease during the period from 1989 to 1995. The PP have reduced from 19 to 12 and ZP from 26 to 16 forms A decrease in forms for all the groups of plankton is indicative of a worsening habitat situation. A shift is also seen in the bluegreen algal composition This is aided by the worsening water quality situation. Ecological improvement measures appear to be urgently needed

Tattaguppe: The PP forms have decreased (13 to 5) but the ZP have marginally increased from (13 to 15). All PP groups have shown decreases. Among ZP, protozoans and rotifers have shown more forms. However, the overall situation appears to have worsened and requires immediate ecological improvement measures Water quality criteria have shown deterioration

Yelchehalli: This lake shows a decrease in both PP and ZP forms over the two survey periods The situation is very bad for PP (11 to 2) and for ZP, the decrease is from 20 to 14 forms. Generally, the decrease is seen in all the plankton groups. The water quality criteria is not very bad. However, by the present form status, there appear to be ecological pressures affecting this lake.

Some more non-urban lakes which are not seriously affected as far as the water quality criteria are concerned but, have shown decreases over the two surveys, in the plankton form diversities are Arehalli, Doddatumkur, Gopalapura, Doddasanne and Kaikondanahalli Changes to a lesser extent are shown by the remaining among the common lakes namely; Budigereammani, Gummanahalli, Madhurekere, Manchappanna- halli, Ardeshanahalli, Bandekodigenahalli and Chikkajala The form diversities have either marginally increased or have remained almost similar

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Annual Waterbird Census in and around Bangalore and Maddur

M.B.Krishna

INTRODUCTION

The Census of wetland and water birds in the Bangalore and Maddur areas of Karnataka State has been an on-going process from the past ten years This report covers the ninth and tenth such censuses conducted so far in these areas for the years 1995 and 1996. There is also a brief review of the results of the past decade (especially bird species occurrence frequencies) in a subsequent part with some preliminary analysis of the data.

EXTENT OF COVERAGE

Around a hundred sites are visited every year by the census team from Bangalore Right from the first year in 1987, when it was started as a modest effort with some five sites being covered, the census has not been confined just to Bangalore alone An approximate thirty five kilometre radius from the GPO has been used as a cut off limit for the lakes of Bangalore. In addition, a stretch along the Bangalore - Mysore highway extending to Maddur and a stretch along the Kanakapura road extending till Harohalli, are also being covered. Basically, all the larger tanks located along all major roads leading out from Bangalore have been selected for the study

CENSUS PERIOD

Conceptually, the middle of January has been chosen as the period most likely to produce reliable results since the birds would have completed their autumn migration and would be well established in their winter quarters. This means that the populations are more or less static from a migration point of view, which greatly reduces the possibility of the same birds being counted elsewhere. In practice, the census period can safely be stretched to include the week before and after the set period, in order that the number of sample sites be as numerous as possible

Here in our area, though most tanks are being covered in January, it has become necessary to extend the census period into February due to the constraints in the availability of trained technical manpower An occasional count has also been taken in March. Moreover the number of sites surveyed makes it impossible for the coverage to be restricted to a short period of time

METHODOLOGY

The field procedure has to include both the birds found in open waters in the middle of lakes and the wading birds found along the shoreline The counting of the open water birds and the birds in the immediate vicinity of the embankment on the down stream side (to about fifty

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metres) was essentially from the elevated embankment The shore and the reed birds have to be necessarily counted by going round the lake along the shoreline If more than one team was involved at any given site, precaution was taken to prevent overlapping counts This was achieved by not only zoning the lakes as above, but also by maintaining records and exchanging information later, on moving and flying birds In the case of large aggregations of birds, gross counts were usually taken first and species-wise counts later Head counts have been taken in almost all the cases Block counting [15] has been used only where very large number of birds occurred together (say, when in excess of around seven to ten thousand birds)

Errors have been minimised at all stages of the survey Field identifications, especially of uncommon species or under difficult conditions, have been double checked by more than one experienced observer At all larger sites, more than one person was invariably there in each counting team Since one person took down all the counts, each of the other observers could concentrate on different bird groups Wherever specific identity was in doubt, the birds were assigned to the next identifiable taxon They are indicated as such in the tables Recounts were made either in the case of large aggregations or in difficult conditions and either lesser or average numbers taken No compensation has been done for sites where complete counting was not possible: the figures indicate the number of birds counted as such and are the lesser estimates of birds at any given site In counting the birds, it has been maintained that one errs on the side of lesser numbers rather than on the higher side

Transcription errors have been reduced by entering data onto the computer directly from the field notes whenever possible Entries were verified as and when they were entered on completion of every set of values, even though it was a slightly slower procedure

The taxonomy used is mostly as in Ripley's list of Indian birds [12] Both field [13, for example] and reference [14, for example] identification manuals have been used as required

PARTICIPATION IN THE CENSUS

The Census has continued as a volunteer effort till date with people even taking leave from their regular work to participate in the bird count As such there are no paid personnel involved in the Midwinter Waterbird Census at Bangalore The following are the people who have participated in the count in 1995 and 1996, with the total number of participation days (both years included) indicated in parentheses

Krishna, MB (22); Ullas, PA (14); Srinivasa, TS (13); Harish Kumar, U (7); Shyamal, L (7); Swamy, NR (7); Hemanth, J (5); Prasad, JN (5); Usha Ramaiah (5); Paresh Karmarkar (4); Subramanya, S (4); Aditya, GS (3); Bhaskar, B (3); Deepali Ramaiah (3); Karthikeyan, S (3); Shanta Manohar (3); Surender Babu (3); Chakrapani, BK (2); Lloyd Nehemiah (2); Raju, AK (2); Subramanya Dixitulu (2); Thyiagarajan, S (2); Anitha, BR (1); Gopi Sundar, KS (1); Leo Saldanha (1); Manoj, (1); Manu Prasanna (1); Naveein, OC (1); Praveen Karanth (1); Sridhara, BA (1); Suma Karmarkar (1); Chatterjee, A (4); Chamundeshwari, T (2); Krishnakumar, YV, ACF (2); Aparajita (1); Beena, R (1); Dev (1); Gopal, V, ACF (1); Kiran Singh (1); Kushalappa, CG (1); Belliappa, M (1); Narayan, BG (1); SA (1); Sudheendra, SV (1); Vittal, BS (1)

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Right from the beginning [20], an attempt has been made to use this event to expose lay-people to the census and make the effort an educational activity. Many therefore, came for the exposure the Census would give, though the number of those who actually counted the birds was not many. The list, thus, includes experienced observers (many of whom have been involved with the Census from its inception), those who have had prior birdwatching experience, students of biology, newcomers who have just made a beginning and on a couple of occasions, even children However, care has been taken throughout to see that identification and counting were done by experienced observers Some experienced observers also went on their own for counting the birds (especially on Sundays, and for the City lakes) and did not make use of transport provided by the Forest Department.

HISTORY OF THE CENSUS

Systematic counts of waterfowl were first taken in England at some 15-20 sites in the latter half of the thirties These censuses lapsed between 1939 and 1947, but were restarted there as a nation wide investigation in 1948 [11]. Regular winter counts were also started at the same time in Holland and Germany, and shortly afterwards in Switzerland Efforts to carry out such counts in Asia were made after the UN "Convention on Wetlands of International Importance - especially as Waterfowl Habitat" at Ramsar, Iran, in 1971 India became a signatory in 1982 and the census as a nation-wide effort was started in India in 1987

The reason for starting the counts in the first place was the growing concern amongst ornithologists and other interested groups at the apparent decline in wetland and water bird populations. The counts were therefore designed to provide a measure of change in their numbers [11] over time The concept was that yearly counts taken at a large number of sites for a long period, would show the trends in the populations of these wild birds.

WETLANDS OF BANGALORE

Wetlands are defined as areas marginal between land and water, inundated or saturated frequently enough to support plant and animal communities adapted to a life dominated by water It encompasses areas of marsh, swamp, standing or flowing water which is fresh, brackish or salty. This definition thus includes man made systems, and the lakes in and around Bangalore fall into this category [3] Apart from the occasional seasonal stream, the Bangalore area has no natural wetlands All the lakes which occur in the area, are thus, man made A wetland of our parts basically consists of an impoundment across a stream to form a lake, and irrigated fields down the embankment As such these usually form a series, a number of them being found in a valley

From an ecological point of view, these lakes form an unique and irreplaceable system locally. A man made lake of our parts can be viewed as a basin with several zones of water of varying depths, abutting a deeper zone that lies towards the embankment This zonation is dynamic and promotes the growth of a variety of emergent, floating, anchored floating and submerged vegetation, each of which shows a preference to a particular range of water depth Again because of the differences in growth habits and structure of these plants, vertically stratified vegetation layers result These fresh water plant communities

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accommodate a large number of small organisms like periphyton, insects, molluscs, etc which form the staple diet of many species of invertebrates and vertebrates in the lakes' food chain

Light, temperature and the availability of oxygen and nutrients govern the growth of plants, of which the smallest and simplest are phyto-plankton, which in turn are devoured by zoo-plankton, insect larvae and fish fry There are even some adult planktonivorous fish and birds Even the lake sediments support a large variety of soil invertebrates which thrive on organic matter from decaying plants and animals These invertebrates are in turn eaten by a variety of other predatory animals such as fish and birds, sometimes along with the sediment itself

Food chains in these lakes can often be complex, lengthening and branching, and forming a food web At the end of this food web is man himself The system is such where almost everything is consumed and reused, and the balance between the various forms of life is very sensitive to change

LOCATION AND SURVIVAL OF BANGALORE'S WETLANDS

A vast majority of our wetland areas occur in the outskirts, on the urban-rural fringe [9] The uneven distribution of Bangalore's lakes with reference to the city at present is obviously the result of the explosive increase in the extent of the city from around 67sqkm in 1961 to over six times that area today [6] The growth of the city has not only engulfed the lake beds but also disrupted the drainage pattern in these basins In addition, the lakes which have survived in the City area have sewage flowing into them Remote sensing studies have revealed that water bodies and wetlands account for just 4.8% of a sample area of 640sqkm covering both urban and rural zones of Bangalore [2] The number of man made lakes, in the existing BCC and BDA area, has fallen from 262 in 1960, to some 81 lakes at present [5] Obviously most of these lakes were created to serve the needs of irrigated agriculture [4], but were destroyed once the pressure for land became high

WETLAND AND WATER BIRDS OF BANGALORE

Over three hundred and thirty species of birds have been recorded in Bangalore and its environs so far [7] Of these, around a hundred and forty bird species are found in or near lakes and wetlands, spread over some nineteen different bird families Wetlands account for a disproportionately large number of bird species compared to the physical extent of the habitat [8] Not all these birds are common, nor are they found in every wetland right through the year: for example, a large number of trans-continental migrants are present only between September and April The occurrence and numbers of birds is a complex interplay of food and resource availability, population movements, water levels and wetland structure, compounded by seasonal fluctuation, disturbance and other factors introduced by man

USAGE OF WETLANDS BY BIRDS

Around forty percent of our bird species occur in or near wetlands or water [9] They make use of a variety of conditions from dry ground and meadows bordering lakes to the open

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water zone. There are also birds which just make use of the open air space above these wetlands. Depending upon their size, the availability of food and suitable conditions for foraging, different bird groups can be seen occupying different regions of the lake. A large number of species can be found in regions with shallow water. Often large congregations of migratory ducks can be found massed on the open waters of large lakes. Sheer distance from the shoreline affords protection to these birds, and they can even be seen sleeping over the water with their beaks tucked-in on their back

The variety of species present does not necessarily mean that all species are equally common. There is a continuous spectrum from the most abundant and widespread species, to those where single individuals of a given species have occurred only once. On the whole, some two thirds of the species are found frequently enough to be termed as "regularly occurring".

MICRO-HABITATS OF WETLAND BIRDS

Amongst the water bird species which occur in Bangalore, there can be some five broad groups which can be recognised based on wetland zones they frequent. Though most species have their preferences, there is some amount of overlap in the usages of these microhabitats. Some species also make use of more than one microhabitat. The five groups are as follows:

Open water birds
Waders and shoreline birds
Meadow and grassland birds
Birds of reedbeds and other vegetation
Birds of open airspace above wetlands

The open water birds are those which keep to the unvegetated open water zone which is generally found in the middle of lakes, away from the shoreline. Ducks, geese, grebes, cormorants, kingfishers, terns, gulls, and Pelican tend to keep to this zone. Except for the ducks and the geese, all the others are fish eating birds generally

Stilt, Greenshank, sandpipers, storks, ibises, Spoonbill, herons, and egrets tend to make use of the shallow waters to wade in and feed. All are long legged, long necked birds which keep to the bare open shorelines, picking up animal matter by either a wait and strike strategy like the herons and egrets, or by actively probing and searching for animals. The larger birds like the herons, egrets, and storks take vertebrate food while the smaller forms feed on invertebrates. The taller birds wade into deeper waters while the short and the short legged birds keep to shallow waters or wet mud.

Rails, bitterns, Coot, jacanas, moorhens, snipe, Painted Snipe, etc make use of the vegetated portions of a wetland. Birds like the jacanas keep to the floating vegetation, their elongated toes enabling the weight to be distributed over the floating leaves. Purple Moorhens are especially attracted to Water Hyacinth covered patches, which they feed on. Bitterns and snipe make use of reed covered areas with standing water beneath, while moorhens and Coot can be seen even swimming out on the open water leaving the vegetation. Other rails usually keep to dense cover.

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Swallows and pratincoles hawk flying insects over water, while wagtails, lapwings and plovers pick insects and other invertebrates off the ground in meadows and fields bordering lakes Birds of prey too make use of the air space over the wetland, searching for suitable animals either perched on a vantage point or by flying over the wetland

In addition to these birds, there are those like weaver-birds and munias which do make use of wetland and other marginal areas to feed and breed. Swallows which forage widely make use of reedbeds to roost-in along with wagtails. In short it can be said that as in other habitats, there are both specialist and generalist users of these micro-habitats.

THE 1995 AND 1996 MIDWINTER WATERBIRD CENSUSES

The results of the 1995 and 1996 censuses can be looked at in two ways The census sites will be taken up first and the species next

THE LAKES

Birds were found and counted in one hundred and twenty one lakes, both with and without water, in the annual censuses of 1995 and 1996. Of these, fifty two had birds in both the years, forty in 1995 and 29 in 1996 alone. In addition there were many dry lakes which did not have any birds at all. These have however not been considered here The lakes are situated in and around Bangalore, and along the Kanakapura road till Harohalli and along the Mysore road till Maddur

Twenty-nine lakes have had twenty or more species found in them in the 1995 and 1996 censuses (*Graph 1*) Byramangala, Hebbal, Hesserghatta, Hosakote, Kalkere, Kanva, Maddur, Rampura, Tailur, Tippagondanahalli and Yellamallappachetty have had this number of species in each of the years. The following had more than nineteen species in only one of the censuses: Anneshwara, Arashinakunte, Ardeshanahalli, Bande-kodigenahalli, Channapattana, Dodda-Tumkur, Hennagara, Hosa-gabbadi, Jakkur, Kagglipura, Kodigehalli, Madhurekere, Manchappanahalli, Nagavara, Nelligudda, Puttenahalli, Sadahalli and Suradhenapura.

If the total number of birds counted at each of the sites is considered, twenty-five lakes have had five-hundred or more birds found in them (*Graph 2*) Byramangala, Bellandur, Hebbal, Hesserghatta, Hosakote, Kalkere, Maddur, Nagavara, Puttenahalli, Tailur, Vartur and Yellamallappachetty had this number in both the censuses. The other lakes which had this number in at least one census are: Agara, Budigere-ammanni, Dodda-tumkur, Harohalli-South, Hennagara, Kanva, Kodigehalli, Madhurekere, Madivala, Manchappanahalli, Puttenahalli, Tippagondanahalli and Yelchehalli.

THE SPECIES

Some one hundred and forty species of birds have been recorded from our wetland habitats, from over three hundred and thirty species recorded in the Bangalore area so far [7] However

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the cumulative species list for the censuses would perhaps be in the order of a hundred species for all these years

SPECIES' POPULATIONS

Nearly ninety-one thousand birds have been counted this year, compared to some fifty-two thousand birds counted in 1995 This indicates that, on the whole, more individuals of species have been counted with the bulk being contributed by ducks Byramangala and Bellandur had around twenty thousand birds each

A comparison of the species totals for 1995 and 1996 by means of a scatter-plot (*Graph 3*) indicates that the counts are positively correlated However, there has been some change with species like the Dabchick, Shoveller, Little Stint, Blackwinged Stilt the Yellow, Grey and White Wagtails, Cotton Teal, etc having increased Greenshank, Gargany, Pintail, Lesser Whistling Teal, Brownheaded Gull etc have decreased in the total birds counted

If the maximum number of individuals per species recorded at any one site is considered and compared for 1995 and 1996 (*Graph 4*), a positive correlation would also result as in the species' totals A scatter-plot would however indicate that the points are more scattered than that in the last "totals" graph, which would mean that the correlation is less strong The species which show an increase in the maximum counts are Shoveller, Dabchick, Little Stint, Cotton Teal, Grey and White Wagtails, Indian Moorhen, etc The species which show a decrease in the maximum counts are Little Egret, Pintail duck, Little Cormorant, Brownheaded Gull, Marsh Sandpiper, Greenshank, etc

LOCAL OCCURRENCE FREQUENCIES OF SPECIES

No species in Bangalore is present in all the lakes simultaneously The Pond Heron, which is the most widespread species, is found in about four fifths of the total number of tanks covered in the census Taking this widespread species as the reference (as 100%), other species fare differently The waders are found in more number of sites than open water birds Little Egret, Common Sandpiper, Green Sandpiper, Spotted Sandpiper, Brahminy Kite, etc follow in that order in the number of sites they occur in Amongst the open water birds, the most widespread is Pied Kingfisher, followed by the Dabchick and Little Cormorant Amongst the ducks, the Gargany is undoubtedly the most widespread, followed by the Pintail Amongst the reed and other vegetation birds, the Coot is the most widespread, followed by the Purple Moorhen and the two snipes: Fantail and Pintail Amongst the meadow-land birds, the Reddwattled Lapwing and the Little Ringed Plover are the most widespread followed by the Yellow Wagtail

As mentioned earlier, the total number of birds counted in 1996 is nearly twice that counted in 1995 Consequently, many species have been found in a greater percentage of sites (relative to Pond Heron) than in the last year A few, however, have also shown a decrease Grey Heron, Pied Kingfisher, and Little Ringed Plover have shown a decrease by 15 8, 9 1 and 8 7 percent respectively, in the frequency of occurrence at different sites Amongst the water birds which have shown an increase, Blackwinged Stilt, Green Sandpiper, Little Cormorant,

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Coot, Purple Heron, and Gargany have shown an increase of 16 9, 15.7, 15.1, 10 1, 9.5 and 8 9 percent respectively. Other species less dependant directly on water have also shown an increase in occurrence They are Pariah and Brahminy Kites, and Yellow, Grey and White Wagtails The Common Swallow was not included in the Census last year but has been covered this year and hence shows a new presence in the tables.

A scatter-plot of the frequency of occurrence of various species in 1996 against that in 1995 (*Graph 5*) shows no glaring deviations This indicates that the occurrence of different species (including unidentified birds) more or less compares equitably between these two years At an absolute level too there have been some changes, with the Pond Heron itself being found in seven less sites this year than in 1995

HABITAT FEATURES AND BIRDS

Presence-absence data on thirty-six habitat parameters were collected during the annual midwinter waterbird counts of 1995 and 1996 This data were subjected to Cluster Analysis and Multivariate Linear Regression, to assess inter-relationships and correlates with bird populations and species richness The details of these parameters along with their co-occurence pattern will be dealt with in the next chapter However, a few points are taken up here

Cluster analysis of the data reveals that, as can be expected, problems and negative impacts do not come alone (*Graph 6*) Many of them co-occur and parameters which indicate a healthy wetland are also associated with each other For example, clear waters are associated with submerged and emergent vegetation while green waters are associated with sewage, effluents and cut margins Algal blooms occur with layouts and extensions coming up near these lakes and muddy waters are associated with mudlifting, pits, brick making and cultivation There are also other similar associations which are revealed by the analysis The cluster analysis in general stengthens many 'common sense' expectations and those derived from prior knowledge and experience Data from one hundred and ninety five site-years have been used for the cluster analysis

A multivarate linear regression using the habitat features as independent variables and the bird species richness or the total bird population as a dependent variable brings out some interesting relationships. Partial correlations were also done simultaneously Data from one hundred and fifty seven site-years have been used for these analyses

Clear water is positively associated with high numbers of species, while green water is negatively so Muddy water does not show a strong relationship, but nevertheless does not seem to be negative Amongst the various vegetational components, submerged, emergent and floating vegetation are positively related to high numbers of species Tree monocultures on the lake bed, mixed plantings on the periphery or barren beds do not show strong relationships Cultivation, grass and meadow on the lake bed, algal blooms and anchored floating vegetation are negatively correlated with high species numbers Considering the various shoreline features, a sloping margin encourages bird species while mud pits, sedimentation, cut and walled margins do not show strong relationships even though some are negative

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If one considers the various uses and abuses lakes are put to, irrigation encourages more species since it opens up new areas and habitats for wading, aerial and shoreline species Tile factories, mud-lifting, garbage (either dumped or washed down), and any kind of washing activity (cattle, vehicle or human) have a negative impact on the number of species found. Activities like fishing, poaching, grazing, land-filling, boating, and the growth of slums and extensions with the associated sewage and effluents seem to be 'targeting' sites with high species numbers.

It should be remembered here that while any species could contribute to an increased variety in any lake, the bulk of the population increase, especially at the larger sites, is contributed by migratory ducks Consequently the relationship with some of the habitat features vary from that for species numbers For example, some amount of floating vegetation seems to greately encourage high populations Growth of extensions, land-filling, human presence around the lake bed like drinking (cattle or human), washing, brick making and slums, grazing, fishing, mud lifting and dark waters, all seem to have a negative impact on high overall populations

The approach here has been that of taking an overview of the whole species spectrum of lakes. There are species which could prefer specific features, but which differ from those aspects which encourage other birdlife Jacanas, for example, are associated with anchored floating vegetation But this type of plant is neither so widespread (which could lead to poor correlations) nor seems to encourage other forms so much. A qualitative summary of lake usage by birds has therefore been given earlier in this chapter to set the background, for the results of the survey.

THE CENSUS DECADE

More than 675 counts have been taken at different sites in the Bangalore and Maddur areas from 1987 to 1996. Some 157 sites have been covered all in all, with most having been indicated in *Graph 7* in relation to the built-up area of Bangalore For the analyses in this section, counts were consolidated site-wise, irrespective of the times the site was visited. Some eighty species of birds have been counted amongst those included in the IWRB census data forms Counts of unidentified species have not been used here. Any change in the data set, for any different analysis, is indicated as such.

MIGRATORY AND NON-MIGRATORY BIRDS

Amongst the species listed in the IWRB form and recorded during the censuses, some thirty nine are migrants and the rest are residents. The status of birds as given in the Annotated Checklist of the Birds of Bangalore has been used here. A site-wise comparison of migrants and residents indicates that both presence and numbers of these two groups are well correlated *Graph 8* compares the number of species recorded over the years while *Graph 9* compares the total identified birds belonging to these two groups. It would just mean that sites which attract birds, do so irrespective of whether species are migrants or residents There seem to be no greatly differing preferences exercised by migratory birds wintering in our area when compared to resident species.

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THE SPECIES RICHNESS OF SITES

Tailur near Maddur is the lake which has the maximum diversity with sixty-four species. Maddur and Jigani follow with forty-two species each. The following listing gives the total number of species recorded (in parentheses) at each of the sites. Lakes with less than a cumulative of seven species (10% of the maximum) have been excluded.

Tailur (64); Jigani (42); Maddur (42); Hennagara (41); Byramangala (40); Hosakote (40); Rampura (40); Kalkere (37); Hebbal (36); Hesserghatta (35); Budigere-ammanni (34); Chikka Sanne (34); Harohalli-s (34); Jakkur (34); Mallurpatna* (34); Yellamallappachetty (34); Dodda Begur (33); Hire Kere (33); Kanchigaranahalli (33); Bidarekere (32); Dodda Tumkur (32); Madivala (32); Yelahanka (32);

Muthanallur (30); Gabbadi-hosa (29); Kodathur (29); Manchappana Halli (29); Odke (29); Rachenahalli (29); Sakalvara (29); Singanayakanahalli (29); Allalasandra (28); Dodda Gubbi (28); Dore Kere (28); Haragadde (28); Kanva* (28); Puttenahalli (28); Anneshwara (27); Bandekodigenahalli (27); Bidaraguppe (27); Harohalli-n (27); Jalige (27); Kaglipura (27); Madhure Kere (27); Nagavara (27); Anchepalya (26); Bellandur (26); Dodda Hulimavu (26); Gabbadi-hale (26); Ganaldoddi (26); Kaggalahalli (26); Suradenapura (26); Thippagondana Halli (26); Ardeshahalli (25); Dodda Jala (25); Kelaginathota (25); Kodigehalli (25); Kommaghatta (25); Singiyyanakere (25); Varthur (25); Chikka Hulimavu (24); Dodda Nekkundi (24); Dodda Sanne (24); Kannamangala (24); Channapattana* (23); Chikka Jala (23); Mugbala (23); Yelchehalli (23); Agara (22); Dasarahalli (22); Gummanahalli (22); Melina Thota (22); Nelligudda (22); Sadahalli (22); Bodhigrama (21); Hullur (21); Kandyara (21);

Arashinakunte (20); Arehalli (20); Bagalur (20); Bhimanahalli (20); Hosa Kere (20); Kengeri-upanagara (20); Vengaiah (20); Gantiganahalli (19); Gopalapura (19); Hennur (19); Mantapa (19); Nelamangala (19); Seshagirihalli (19); TatKere* (19); Hoskerehalli (18); Kogilu (18); Chikka Begur (17); Dyavasandra (17); Lalbagh (17); Obichudanahalli (17); Somanahalli (17); Attibele (16); Binnamangala (16); Bommashettyhalli (16); Kaikondanahalli (16); Kannehalli (16); Kudlur* (16); Kumbalagodu (16); Nagaruru-kodipalya (15); Tatguppe (15); Byappanahalli (14); Chikka Hoskote (14); Gottigere (14); Gulimangala (14); Kodi Halli (14); Somanahalli* (14); Alur (13); Huskur-s (13); Shettihalli* (13); Whitefield-nallurhalli (13); Gundappanahalli-K (12); Rayasandra (12); Singena-agrahara (12); Taralu (12); Arakere (11); Channammanahalli* (11); Dodda Togur (11); Nalsandra (11); Nayandahalli (11); Neralur (11); Sankey (11); Sarjapura (11); Thomsandra (11);

Ammanimuli (10); BNP-ALL-5 (10); Doddana (10); Karmalaram (10); Kenchapura (10); Madarahalli (10); Channapatna KEB Office* (9); Halnayakanahalli (9); Tavare Kere (9); Vasudevapura (9); Anekal (8); Gunjur (8); Kempabudhi (8); Naganathapura (8); Anakanagondi (7); Channahalli (7); Guttepalya (7); JP-nagar (7); Ravagodlu (7); Rayarakere (7); Ulsoor (7); Uttarahalli (7)

A few of these lakes are no longer existing! The lakes indicated in *Graph 7* have been used for zoning of the area in *Graph 10*. The latter graph is meant to give a broad overview of the species rich and species poor areas. It can be noticed that there is a general high richness zone extending from SW (Maddur area) to NNE. The NW (Tumkur road) and the SE (between Sarjapur & Hosur roads) are poor in species, both being close to heavily industrialised areas. The high species richness points of Kanakapura road on one side and that of the Jigani & Hennagara areas on the other side of Bannerghatta range highlights the low number of lakes in the Bannerghatta range. For a detailed perspective, one needs to look individually into the disposition of the larger lakes and those with a high species richness.

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CLUSTER ANALYSIS

Site- and species- wise consolidated totals of all years were made use of for the cluster analysis [16, 17] of both birds and lakes. An unweighted pair group average method was used with the distance measure being a chord index and Jaccard's index for the site-wise comparisons and rank correlation coefficient, product-moment correlation coefficient and Jaccard's index for the bird species. Other 'binary' indices like Dice's and Yule's were tried out earlier on data compiled till 1995 but have not been used now. Rank correlation for the birds and chord index for the lakes seem to give biologically meaningful results

The data matrix was first sorted in a descending order on occurrence frequencies and numbers for both birds and lakes before subjecting it to the analysis. This was to avoid random placements and provide more easily comparable dendrograms with replicates of data sets, especially for species. This was done intentionally so that less frequently occurring species (or lakes with lesser number of species), would get more towards one side of the dendrogram, which ever way the data matrix was used to generate the distance matrix. This way, one would know that variables towards one side would be generally less common than the ones on the other side of the dendrogram, though the level of the linkages would itself indicate the strength of the relationship.

Graph 11 and *Graph 12* show the results of a cluster analysis using chord index and unweighted pair group method for 1995 and 1996 data. All the taxa, including the unidentified species which were grouped into the next taxonomic level have been used for the analysis. A vast majority of the lakes with medium to low diversities and populations are clustered together while those with high diversities or populations like Tailur, Hebbal and Maddur stand out on separated branches

Graph 13 is the dendrogram for lakes using the Chord index and unweighted pair group clustering for the site-wise consolidated counts taken over the decade. Only the identified species listed in the IWRB forms have been used. A similar pattern as observed in the individual years' dendrogram is also obtained here. The number of groups formed would vary depending on the reference level for the linkages: weaker the linkage, larger the groups; and stronger the linkage, smaller the groups

Graph 14 is the dendrogram obtained for bird species using rank correlation and unweighted pair group clustering. The dendrogram reflects what could be expected from the biology of the species. Many of the birds on paired branches are indeed those which frequently occur together, like Pond Heron and Little Egret, Pintail and Garganey, Large and Median Egrets, etc. A combined count for each species for each site would mean that even though the species may not have occurred together at a given site at a given time, the overall suitability of the habitat for the species would get the importance. Thus, while one can come across a Pond Heron and a Little Egret in almost every pond, almost expecting it to co-occur, the dendrogram does bring up some interesting combinations, like the land walking Cattle Egret and Redwattled Lapwing, on paired branches. It must be remembered here that shorebirds are generally more widespread than open water birds like ducks, which tend to congregate in large open expanses of water

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This note on cluster analysis is only to indicate possibilities It is by no means a comprehensive interpretation of the results There are also other methods, like various ordination techniques, which could hold promise. For example, the first axis of a detrended correspondence analysis using reciprocal averaging seems to order the consolidated data of lakes quite well in a way which seems to be biologically meaningful. However there are oppurtunities to realise more out of all these techniques in our situation and the analyses presented here are just preliminary in nature.

ON THE OCCURRENCE FREQUENCIES OF SPECIES

It is habitats and sites (lakes) which are more threatened locally, rather than the bird species themselves All the water birds in our area are found elsewhere in India too, and as such are not exclusive to our parts Since a bias towards habitats could have a greater value for monitoring purposes, it has been thought appropriate to make use of frequencies (which relate directly to sites) here, rather than the absolute numbers of birds

A comparison of *Graph 1* with *Graph 5* indicates that the number of species found at different sites is more variable from year to year, rather than the frequency of occurrences of the species themselves This would be good for the monitoring of sites since the species themselves show not much of change, as sites do!

The product moment correlation coefficient between the occurrence frequency percentages for a hundred species (both from the IWRB list and those like wagtails, etc) for 1996 and 1995 would be +0 948. Over the decade, the average correlation coefficient with a lag of one year would be +0 902 (9 values) With a lag of two years, it would be +0 874 (8 values); with a lag of three years, +0.843 (7 values); and with a lag of four years, +0 820 (6 values) This indicates that the overall ratios between the occurrence of species is amazingly constant at least over the decade!

SPECIES RICHNESS AND POPULATION TRENDS OVER THE DECADE

A visual and graphical examination of the total numbers of species and birds found at the various sites over the decade show no apparent trends Examination of groups of lakes with similar species richness also shows no apparent trends in the number of species or populations This however, does not mean that year to year fluctuations are not present, but would only indicate that on the whole, populations and species are not decreasing or increasing in Bangalore over the decade

REMARKS

Obviously, there is no single factor which regulates the presence and numbers of bird species in and around our lakes and wetlands. Water-spread and length of shoreline would naturally be dominant determinants. Human activity in and around the lake would perhaps also exert great influence In the case of migratory birds, habitat conditions in North India would also be responsible for the variation of species and numbers come across every year [3]

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The next chapter deals with the status of these sites and the various human pressures they are subject to. Even without considering those cases where careful monitoring is possible right through the year, an annual visit itself indicates that the quality of the various sites is deteriorating, with lakes almost getting 'boxed-in'. We therefore, cannot certainly feel complacent that the lake bird habitats in the area are safe!

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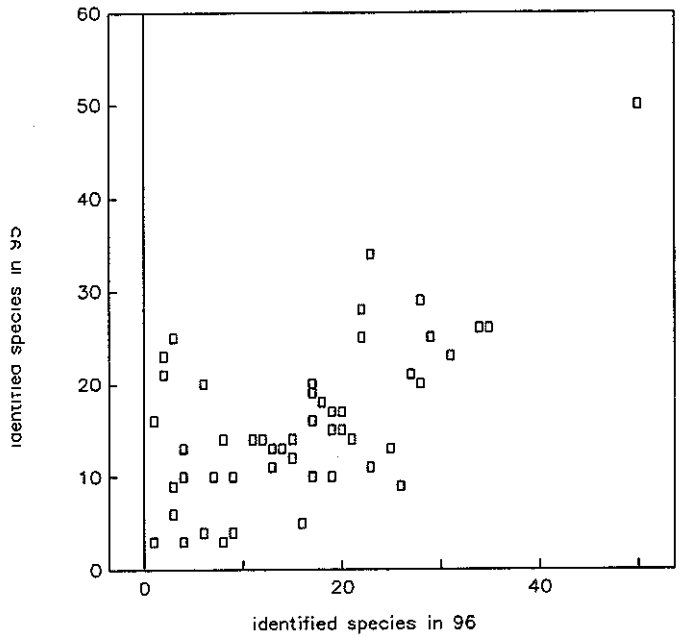
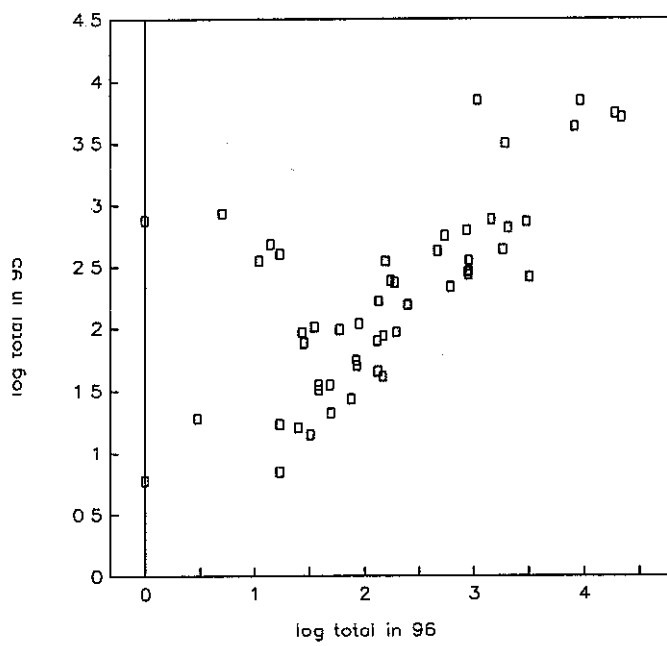


Graph 1. Comparison between the 1995 and 1996 censuses in the number of species recorded at each of the lakes



Graph 2 Comparison between the two censuses in the total number of birds counted at each of the lakes

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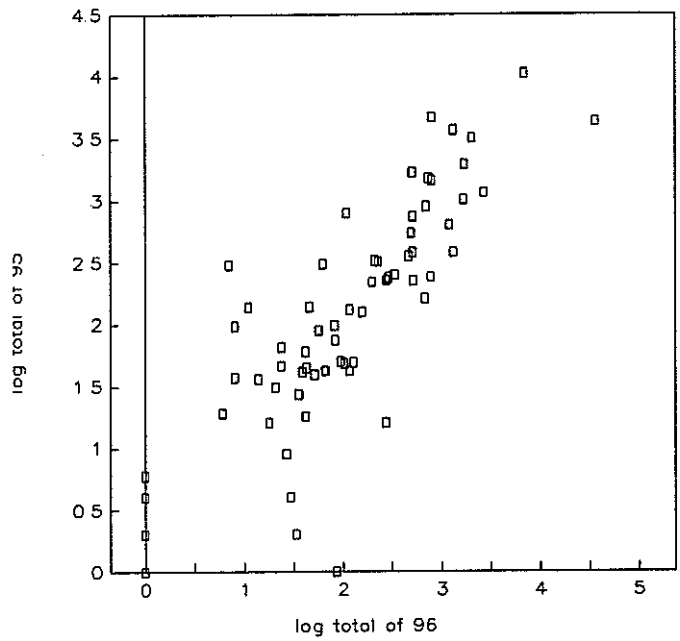
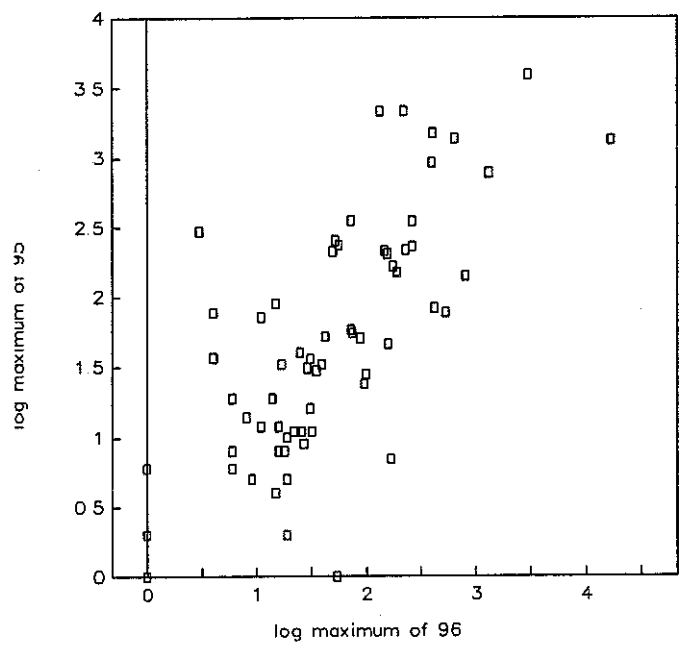


Graph 3. Species-wise comparison between 1995 and 1996 in the total number of birds counted



Graph 4 Comparison between the two censuses in the maximum number of birds counted per species

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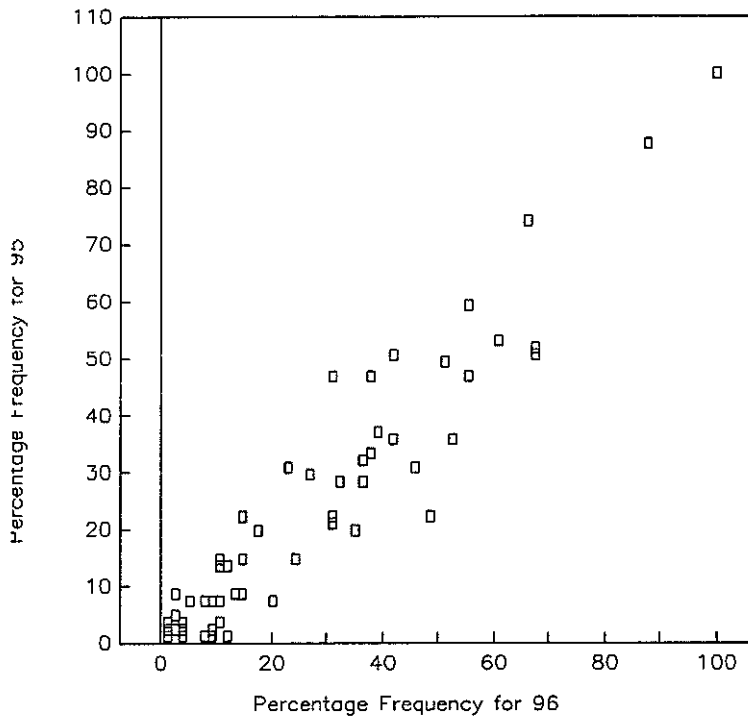

Graph 5 Frequency of occurrence of different species and unidentified groups in 1995 and 1996

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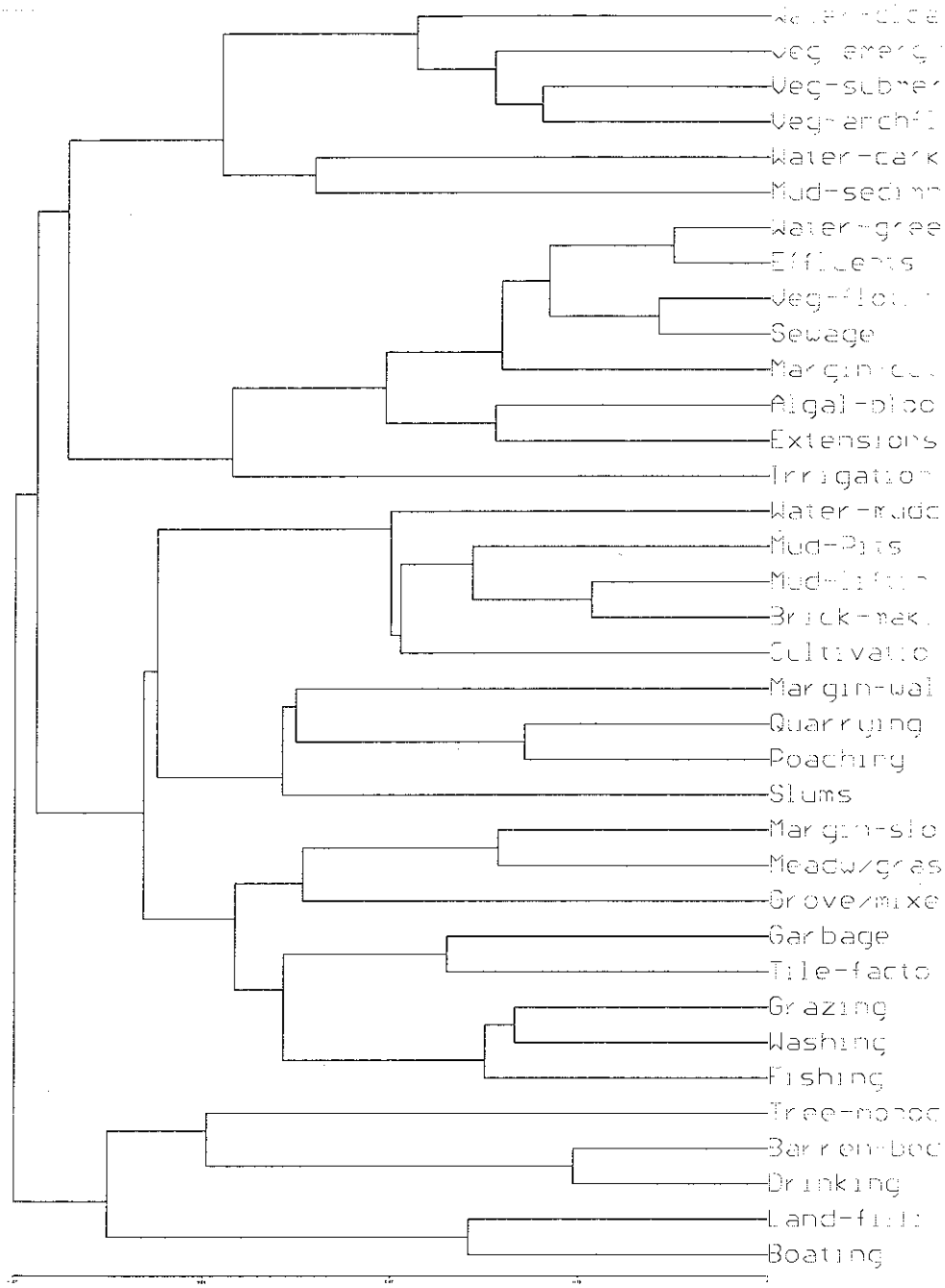

Graph 6 Dendrogram showing the relationship between various habitat parameters recorded during the 1995 and 1996 surveys Yule's index and unweighted pair group clustering

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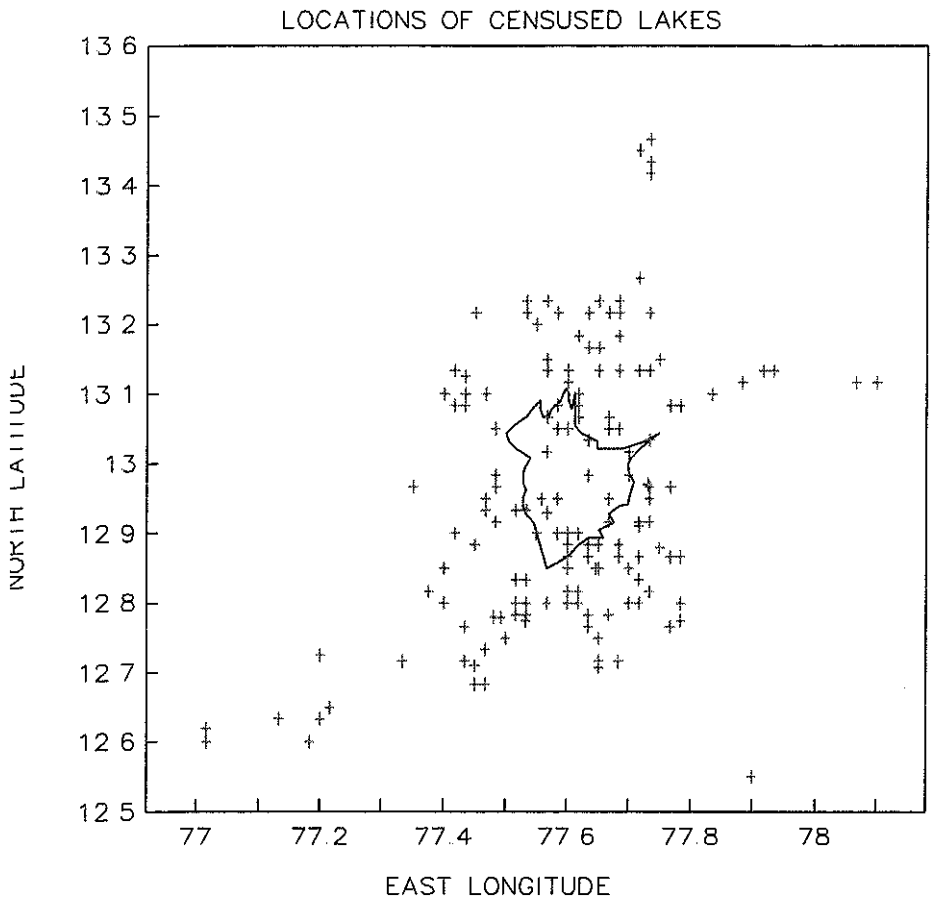

Graph 7. Locations of the censused sites in and around Bangalore and Maddur. The outline shown is that of built-up Bangalore The co-ordinates are in degrees & decimals, and not in degrees & minutes.

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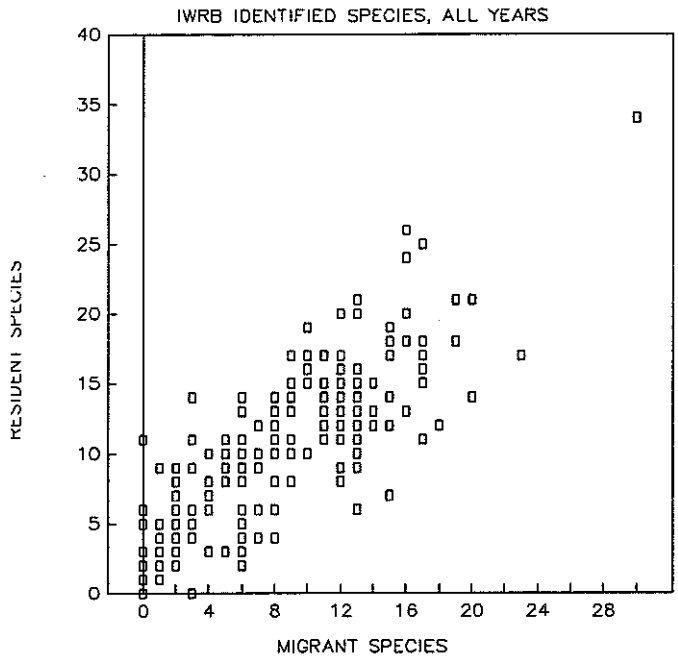
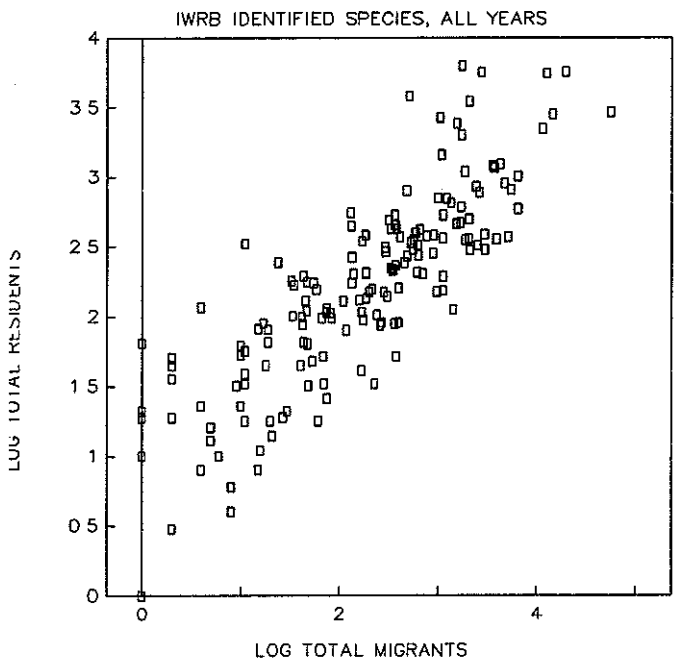


Graph 8. A comparison of the total number of migratory and non-migratory water bird species (as listed in the IWRC census form) found at sites over the censusing decade.



Graph 9. A comparison of identified migratory and non-migratory water bird species' (as listed in the IWRC census form) cumulative totals found at sites over the censusing decade

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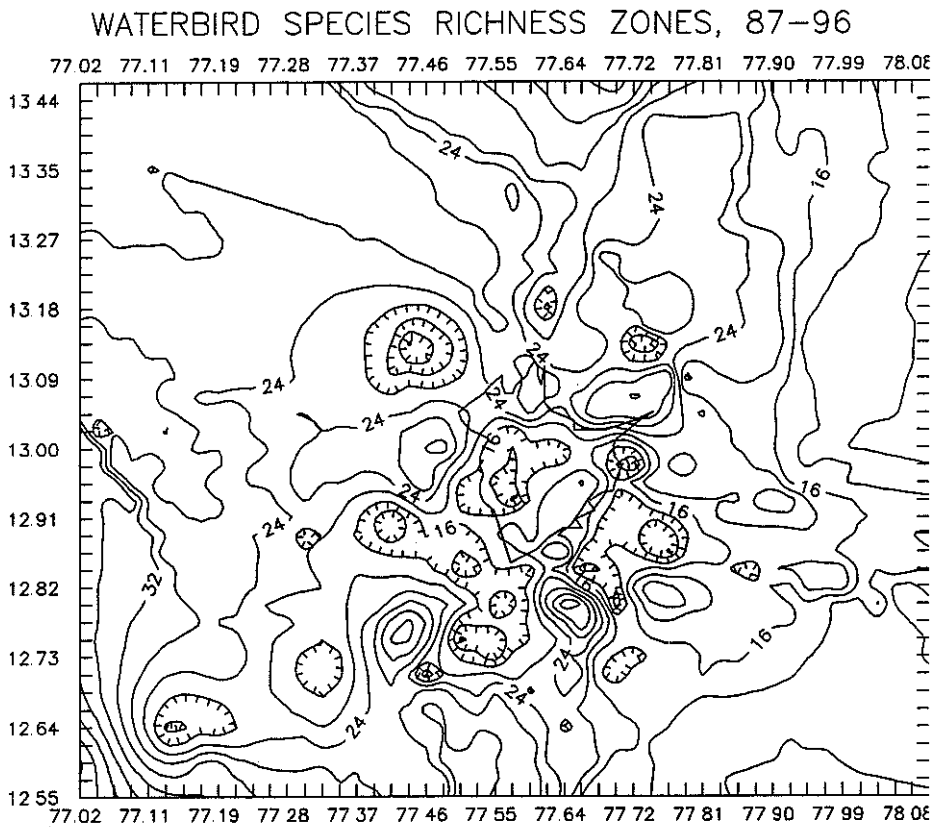

Graph 10. Zoning of the Bangalore area based on the cumulative number of water and wetland bird species recorded over the decade of censusing. The co-ordinates are in degrees & decimals, and not in degrees & minutes. The species considered are only those included in the IWRB census forms. The contours are smoothed using a cubic spline and the "lows" hatchured The gridding is based on kriging with duplicate points averaged.

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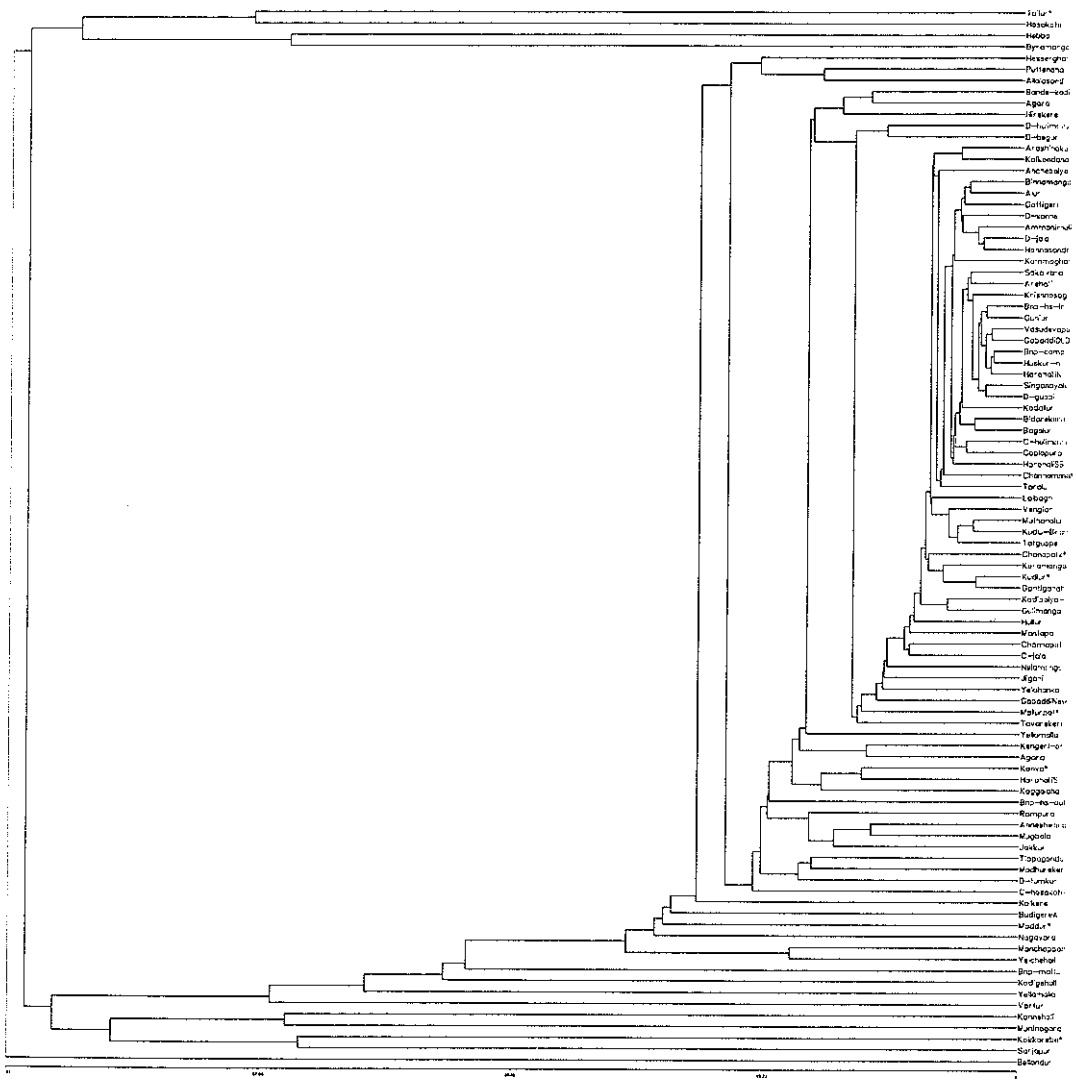

Graph 11 Dendrogram of lakes using 1995 data. Chord index and unweighted pair group clustering.

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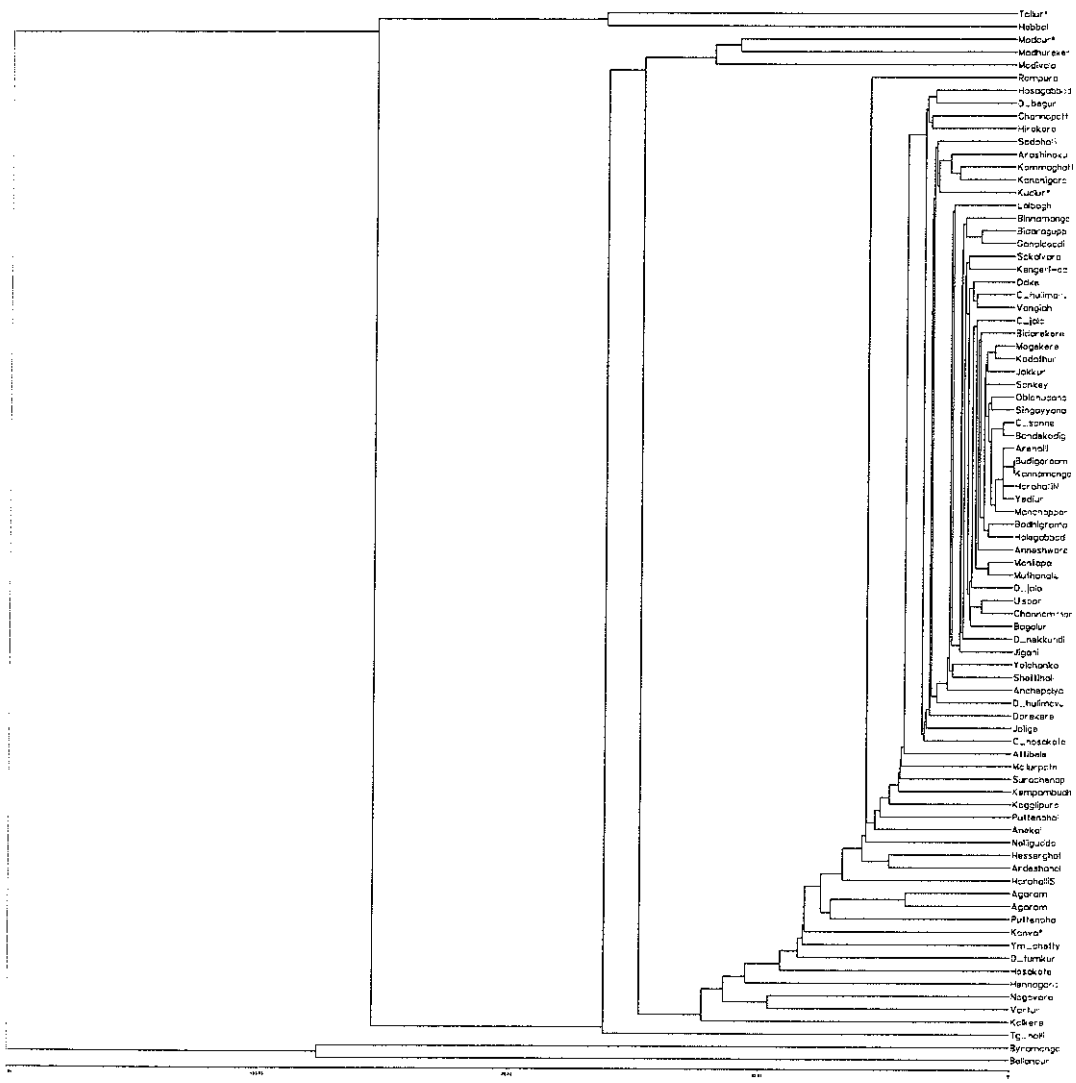

Graph 12 Dendrogram of lakes using 1996 data. Chord index and unweighted pair group clustering.

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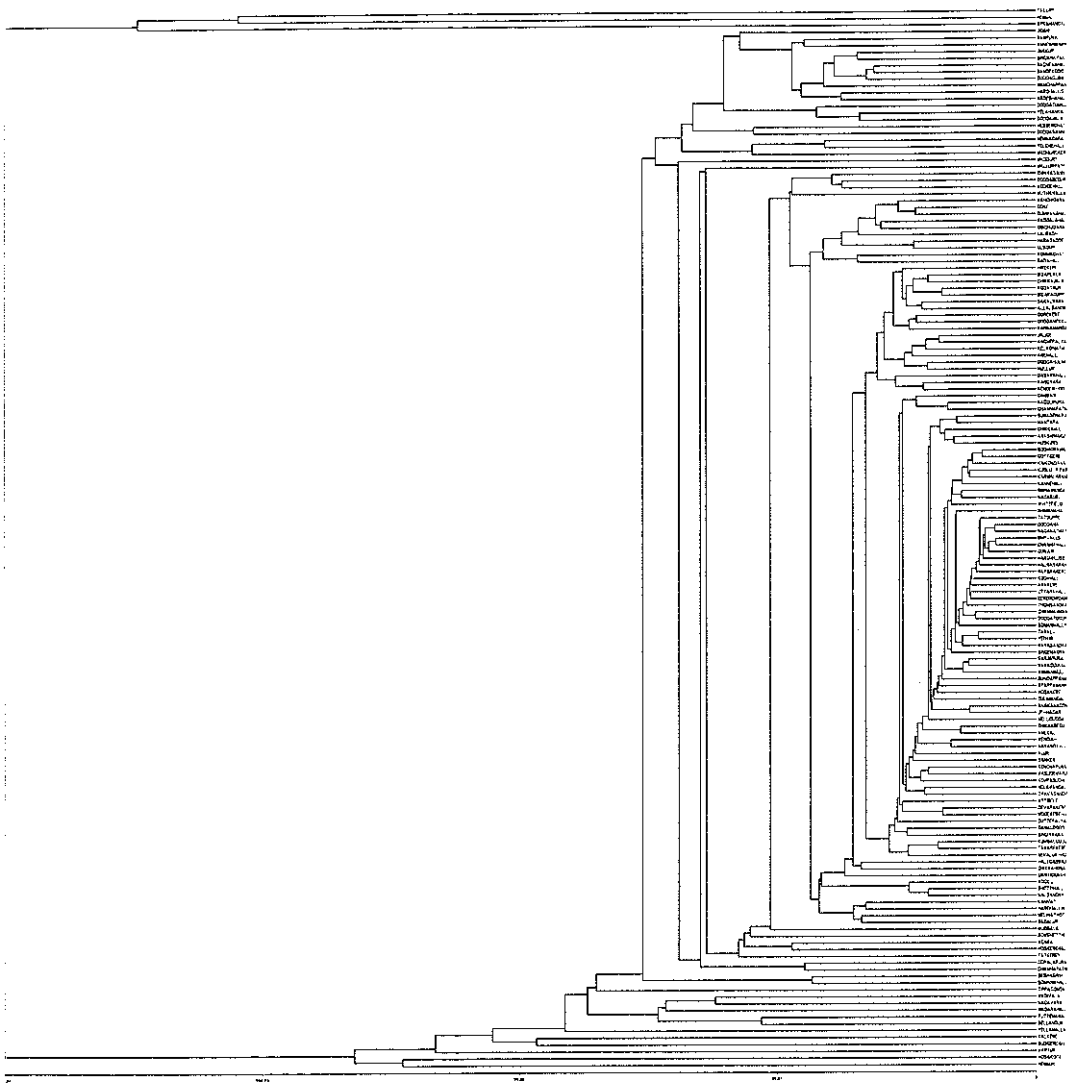

Graph 13 Dendrogram of lakes using the decade's consolidated data. Chord index and unweighted pair group clustering Tank names are abbreviated

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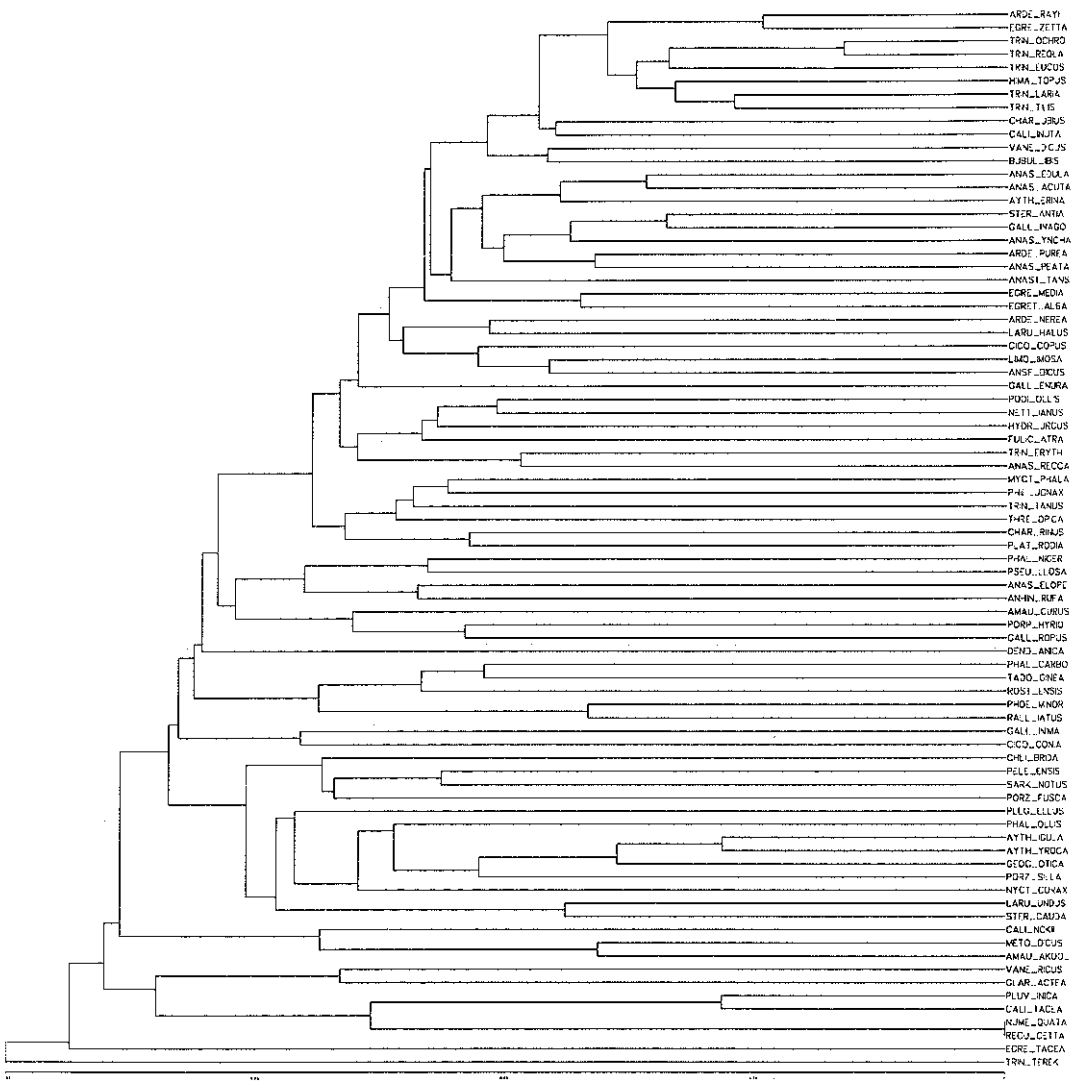

Graph 14 Dendrogram of bird species using the decade's consolidated data. Rank correlation and unweighted pair group clustering. The first four letters of the generic name and the last five letters of the specific name have been used for the labels.

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